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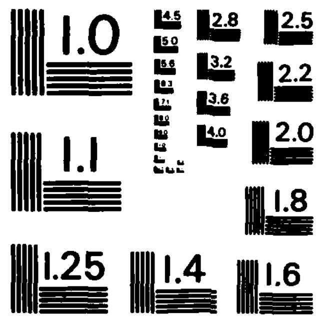

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# CRREL
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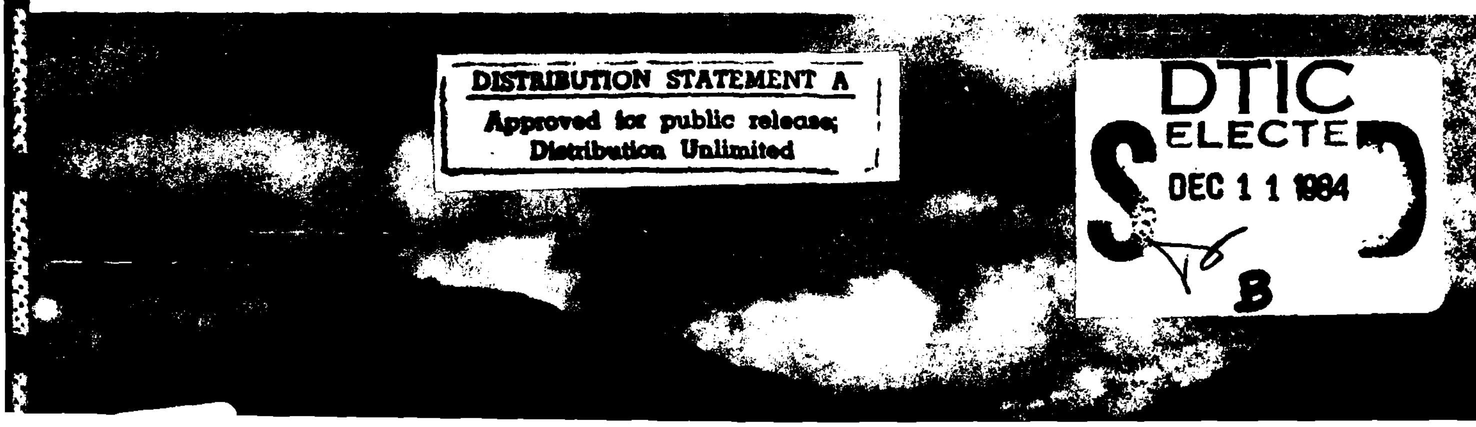
AD-A148 429

# *Regional and seasonal variations in snow-cover density in the U.S.S.R.*



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# CRREL Report 84-22

August 1984

# *Regional and seasonal variations in snow-cover density in the U.S.S.R.*

Michael A. Bilello

Prepared for
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Regional and seasonal variations in snow-cover density (SCD) in the U.S.S.R. were determined through the analysis of data obtained from all available Soviet literature. A relationship found between observed winter wind speeds and SCD values recorded from November through March made it possible to develop a snow-density map of the U.S.S.R. The map was divided into five general categories of SCD, ranging from values of $\leq 0.21$ g/cm³ at interior stations with very light winds to values of $\geq 0.31$ g/cm³ at arctic locations with strong winds. Since this literature survey indicated that the reported Soviet SCD values were incorrect due to instrumental errors, adjustments to the data in this study were required. Month-to-month investigation of the SCD data revealed a gradual increase in density from November to March and that the SCD values under forest canopies averaged from 4 to 14% lower than those recorded in open areas. Also

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20. Abstract (cont'd).

included in this report are 1) a compilation of pertinent passages in the Soviet literature on SCD, 2) a map showing the location of SCD measurements, and 3) an average winter wind speed chart for the U.S.S.R.

## PREFACE

This report was prepared by Michael A. Bilello, Meteorologist, formerly of the Geophysical Sciences Branch, Research Division, U.S. Army Cold Regions Research and Engineering Laboratory. The work was performed under DA Project 4A762730AT42, *Design, Construction and Operations Technology for Cold Regions,* Technical Effort E1, *Environmental Control Methods,* Work Unit 005, *Winter Battlefield Climatology.*

Assistance in the effort of conducting the comprehensive survey of Soviet literature required for this study was provided by the library personnel at CRREL. The collection of climatic information for the U.S.S.R. was accomplished through the cooperation of the U.S. Air Force Environmental Technical Application Center (ETAC). The investigation was performed in conjunction with the SNOW Experiments Project under George Aitken, Program Manager.

The author wishes to express his appreciation to Dr. George Ashton and Dr. Anthony Gow for their technical review of the report and to Roy Bates who extracted the data from ETAC files. A note of thanks is also due to Mark Winkler for his assistance in the data analysis, to Edmund Wright for the expert editorial review of the text, to Nancy Richardson for the extensive typing of the drafts and final manuscript, and to those individuals in the publications and drafting sections of CRREL who helped in the preparation of the report.

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Table

# REGIONAL AND SEASONAL VARIATIONS IN SNOW-COVER DENSITY IN THE U.S.S.R.

Michael A. Bilello

## INTRODUCTION

In a previous study (Bilello 1967), snow-cover density (SCD) observations made from the beginning of November through March were used to develop an average seasonal SCD map for northern North America. The study investigated the relationship between climatic variables and regional variations in SCD and showed that the data could be grouped into four categories of snow density. The objective of the study described here was to adopt the approach used previously and to develop a similar map for the U.S.S.R. This report also includes excerpts of pertinent SCD data from the Soviet Union, and other associated maps obtained from a survey of available publications.

Some significant areas in which the results of these SCD studies would be applicable to winter environmental technology are 1) the thermal effects of snow density on the depth of frost penetration in the ground and on the growth of ice on water bodies, 2) the role of snow density in the ability for wheeled or tracked vehicles to move over snow-covered terrain, 3) the problems associated with snow removal on roads or buildings and 4) the importance of snow density data in various hydrologic and agricultural activities that contribute to the national economy.

With recent advances in aerial photography and satellite imagery, knowledge of specific features of the earth's surface in winter, such as the snow-cover density, is becoming particularly useful in a number of interpretative analyses. Information on the physical characteristics of the snow cover, especially its density, is essential in the analysis of photographs or satellite images of a snow-covered terrain.

## SOVIET SNOW-COVER DENSITY DATA

### Soviet sources

An important source of Soviet data sources resulted from a United States–Soviet Scientific Exchange Visit to the Kolyma Water Balance Station in the Magadan Oblast, U.S.S.R., by the author and a representative of the U.S. Forest Service (Slaughter and Bilello 1977). During this trip, the watershed hydrology, instrumentation, field practices, and Soviet snow research objectives were reviewed. In addition to the useful discussions regarding snow measuring equipment and snow-cover conditions observed in that area of the country, the author later received a copy of a book by Kopanev (1978) entitled *Snow Cover in the U.S.S.R.* Average monthly SCD measurements made at hydrometeorological stations across the U.S.S.R. were tabulated in this book.

Additional SCD data were provided to the author in 1981 by a member of the Soviet Academy of Sciences. Observed densities for 105 locations in the Soviet Union were used in the development of a map on the regional distribution of SCD. The application, adjustments, and analysis of these data are discussed in detail later in the report.

#### Literature sources

The 36 volumes of the CRREL *Bibliography on Cold Regions Science and Technology* (U.S. Army Cold Regions Research and Engineering Laboratory 1951–1982) were used as the primary source for a comprehensive search for information on SCD in the Soviet Union. A search through the 36 volumes provided a substantial list of articles on the subject under study. Further examination of the abstracts of the selected references revealed 24 Russian articles that contained information pertinent to this study and many other papers that presented snow-cover research not directly applicable to this study. The following procedures for incorporating the pertinent SCD material given in these Soviet articles were used in this report.

#### Pertinent SCD articles

The 24 Russian articles that provided information on SCD in the Soviet Union were translated (when necessary) and pertinent subject material was extracted and included as an appendix to this report (App. A). A review of information given in Appendix A indicated that it would be worthwhile to further extract all the quoted *numerical* values on SCD and to tabulate the data with respect to the area in which they were recorded. These areas were then located on a map (Fig. A1) of the U.S.S.R. so that the reported densities could be easily associated with the areas to which they apply. Statements of interest regarding snow cover conditions and further details on the data summaries are given in Appendix A. The 24 references that were used for this survey are also listed in the appendix.

#### Other articles of interest

The numerous articles that appear to provide interesting and possibly useful information on snow-cover characteristics across northern Eurasia are listed separately as a CRREL Internal Report 840. This list of over 150 items includes articles prepared in languages besides Russian. However, except for their titles (and some abstracts) the foreign papers were not translated. The bulk of these papers provided results of research on essential aspects of the snow cover such as 1) instrumentation and field measurement evaluations, 2) snow conditions in specific regions of the U.S.S.R. and in other European countries, 3) areal variability in snow properties due to elevation and exposure, and 4) interrelationships between the snow cover and hydrology and/or meteorology.

## UTILIZATION OF SOVIET SNOW-COVER DENSITY DATA

#### Station selection

Although average monthly SCD values for 137 field locations were provided by the two Soviet sources, the data for only 105 of those stations were used in this study. The other 32 Soviet stations were excluded for the following reasons:

1. Since no information was provided regarding precise locations of any of the reported stations, it was necessary to determine and verify the exact coordinates for each site. Three sources were used to obtain this information: 1) an official standard name gazetteer for the U.S.S.R. (U.S. Army 1970), 2) a National Geographic Society Map of the Soviet Union (National Geographic Society 1976), and 3) an Army Map Service, Asian Series Map (U.S. Army 1962 and 1964). Latitude and longitude values, to the degree and nearest minute, based on at least two of the above three sources were obtained and verified for the 105 stations. Confirmation of the position of many of the other sites could not be determined because a number of different coordinates were given but the correct one could not be ascertained. Other excluded locations were not listed in any of the above sources.

2. Density readings for only three winter months were provided in the tabulations for some of the stations. As noted below, the period from November through March was used to compute an average "seasonal" SCD. This portion of the winter was also used in the North American study because it generally includes months with below-freezing average air temperatures. It was decided, therefore, that a 3-month "winter" would be too brief for inclusion in this investigation.

3. A few stations were found to appear in both the Soviet data sources. In these cases, the reported densities were compared for verification purposes and the station was listed only once.

#### Data discrepancies

The author's initial optimism regarding the

SCD values received from the Soviet sources for this study gradually diminished after further evaluation of the data. The first indication of a problem arose when the reported SCD values for the Soviet Union were compared with those observed across northern North America. Stations that exhibited very similar winter climatic regimes (for example, arctic stations that recorded very cold temperatures and strong winds or inland stations with cold air temperatures but very light winds) were used in the comparison. Results from representative stations within these regimes showed that average SCD's for the Soviet stations ranged from 18 to 27% lower than those recorded in North America.

These disagreements could perhaps be explained by differences in the method of observation, the length of records, and the procedures for computing the average density values. Since no specific information is available on any of these points regarding the Soviet data, the degree of their influence on the issue could not be determined. Nevertheless, the discrepancies were large enough to prompt further investigation of possible causes.

**Soviet observational errors**

Subsequent scrutiny of available translated Soviet literature revealed the following significant quotation in a paper by Kolesov (1979):

> A paper by Zmieva and Subbotin has appeared recently in which the results are reported of special measurements of the water equivalent of snow performed in the Medvenka River Basin for the purpose of determining the magnitude and reasons for errors in snow density determinations. It was found that systematic errors reaching 20-30 and even 50% occur when snow density is measured with standard density meters.

Since this disclosure was critical toward reaching a possible solution to the dilemma, a translated copy of the paper by Zmieva and Subbotin (1977) was retrieved. The results of their investigation on the accuracy of snow water equivalent with the standard Soviet densitometer are summarized in the following (quoted) four points:

> 1) Substantial systematic errors of the same sign (on the low side) reaching 20-30 and even 50%, rather than the 7-12% indicated in the Handbook, may arise in measurement of snow densities with the standard densitometer (especially new ones). The largest measurement errors are obtained at low air temperatures when the snow cover has a fine-grained structure with ice interlayers;
>
> 2) The instrumental error of determination of the maximum water equivalents when there is a wide air-temperature range on a given day can be reduced somewhat by making the snow survey in the latter half of the day instead of in the early morning after an overnight frost;
>
> 3) To lower the possibility of measurement errors due to clogging of densitometer by the column of snow, it is necessary to take the samples layer by layer, no more than 25-30 cm at a time;
>
> 4) In some cases, new tin plated densitometers may have the largest errors in snow-density determination because the inner walls are rougher than those of old, polished instruments. Attention should be given to the development of new methods and instruments for measurement of the density and water equivalents of snow cover.

Further evaluation of the information given in the text of the Zmieva-Subbotin paper disclosed the following:

1. When a single-step procedure was used to determine SCD with an earlier type standard densitometer, the measured values were 10 to 15% too low; if a layer by layer procedure was used with the earlier equipment the values were 20 to 30% too low.
2. Single step procedures with a new type of densitometer (one with a rougher inner surface) produced low readings that often exceeded 30%, especially on frosty days.
3. Early morning observations (i.e. the colder part of the day) resulted in readings that were 10 to 15% lower than the evening observations.
4. When measuring snow covers with crusty or icy layers, a controlled test consistently gave higher density values than those obtained from the routine densitometer method.

**Data adjustment**

It became obvious from these revelations that an adjustment to the SCD data obtained from the Soviet sources would be both necessary and justified. After considerable discussion and review of the facts and figures concerning the problem, it was decided that a correction factor of plus 20% on the data for all the stations would be warranted. Of course, several other adjustment schemes could have been adopted, such as a range in correction amount (e.g. from +15 to +25%). Unfortunately, the application of such an approach would require additional insight as to where and why one station would justify a higher or lower correction factor over another. Since no details on the observational techniques are available for any of the reporting stations, attempts to further refine the adjustment factor would be very subjective.

It should be noted that further inspection of the Soviet monthly SCD values (especially those given in Kopanev) revealed a few obvious unrepresentative values. For example, the station Chishmy reported values of 0.16, 0.21, 0.22, 0.23 and 0.18

**Table 1. Average seasonal snow-cover density (g/cm³) for stations in the Soviet Union. Data based on snow surveys made during the last 10 days of the month for November through March in 1) open field areas, 2) forest clearings, and 3) under a forest canopy.**

| Station | Coordinates Lat(N) | Coordinates Long(E) | Areas 1, 2 or 3 (as noted above) | Avg. seasonal snow-cover density* (g/cm³) |
|---|---|---|---|---|
| Aleksandrov | 56°24′ | 38°43′ | 1 | 0.274 |
| | | | 2 | 0.258 |
| Aleksandrovskoye | 60 26 | 77 52 | 1 | 0.269 |
| Amazar | 53 52 | 120 53 | 1 | 0.180 |
| | | | 2 | 0.180 |
| | | | 3 | 0.168 |
| Amga | 60 53 | 132 00 | 1 | 0.206 |
| Anuchino† | 53 45 | 44 57 | 1 | 0.274 |
| | | | 2 | 0.247 |
| Arkagala | 63 09 | 146 47 | 1 | 0.204 |
| Bakchar | 57 01 | 82 05 | 1 | 0.257 |
| Baunt | 55 16 | 133 08 | 1 | 0.168 |
| | | | 2 | 0.154 |
| Berezovo | 63 56 | 65 03 | 1 | 0.245 |
| | | | 3 | 0.209 |
| Birobidzhan | 48 48 | 132 57 | 1 | 0.211 |
| | | | 3 | 0.194 |
| Blagoveshchensk | 50 16 | 127 32 | 1 | 0.218 |
| | | | 3 | 0.166 |
| Bogandinskoye | 56 54 | 65 53 | 1 | 0.242 |
| | | | 3 | 0.228 |
| Bogotol | 56 10 | 89 35 | 1 | 0.298 |
| | | | 3 | 0.266 |
| Bochevaya | 47 46 | 135 38 | 1 | 0.206 |
| Bugulma | 54 33 | 52 48 | 1 | 0.283 |
| | | | 3 | 0.223 |
| Chelyabinsk | 55 09 | 61 24 | 1 | 0.252 |
| Chernigov | 51 30 | 31 18 | 1 | 0.302 |
| Chishmy | 54 54 | 54 40 | 1 | 0.252 |
| Danilov | 58 12 | 40 10 | 1 | 0.266 |
| | | | 2 | 0.266 |
| | | | 3 | 0.245 |
| Debal'tsevo | 48 20 | 38 24 | 1 | 0.302 |
| Dem'yanskoye | 59 36 | 69 18 | 1 | 0.242 |
| | | | 2 | 0.223 |
| Dolgiy Most | 56 45 | 96 48 | 1 | 0.250 |
| | | | 3 | 0.226 |
| Dudinka | 69 24 | 86 15 | 1 | 0.283 |
| Dzerzhinskoye | 56 50 | 95 13 | 1 | 0.230 |
| | | | 2 | 0.221 |
| | | | 3 | 0.222 |
| Dzhanky | 69 46 | 135 04 | 1 | 0.182 |
| | | | 3 | 0.170 |
| Gigant | 46 30 | 41 20 | 1 | 0.290 |
| Gor'kiy | 56 20 | 43 59 | 1 | 0.283 |
| | | | 2 | 0.252 |
| | | | 3 | 0.242 |
| Indiga | 67 39 | 49 02 | 1 | 0.355 |
| Kaluga | 54 31 | 36 16 | 1 | 0.290 |
| | | | 3 | 0.245 |
| Kamenka | 58 33 | 95 51 | 1 | 0.254 |
| | | | 2 | 0.233 |
| Karaganda | 49 48 | 73 08 | 1 | 0.290 |

* Data obtained from Soviet sources and adjusted by +20% (see text).

† Same station name given for two different locations (see Appendix C).

Table 1 (cont'd).

| Station | Coordinates Lat(N) | Long(E) | Areas 1, 2 or 3 (as noted above) | Avg. seasonal snow-cover density* (g/cm³) |
|---|---|---|---|---|
| Saskylakh | 71 58 | 114 05 | 1 | 0.240 |
| Semenovka | 52 10 | 32 35 | 1 | 0.306 |
| Serpukhov | 54 55 | 37 25 | 1 | 0.283 |
| Shadrinsk | 56 05 | 63 38 | 1 | 0.298 |
| | | | 2 | 0.252 |
| | | | 3 | 0.240 |
| Shugozero | 59 55 | 34 12 | 1 | 0.254 |
| | | | 2 | 0.238 |
| Solikamsk | 59 39 | 56 47 | 1 | 0.293 |
| | | | 2 | 0.247 |
| Sretensk | 52 15 | 117 43 | 1 | 0.211 |
| Staritsa | 58 11 | 80 40 | 1 | 0.238 |
| | | | 3 | 0.209 |
| Sterlitimak | 53 37 | 55 58 | 1 | 0.278 |
| Sukhobuzimskoye | 56 30 | 93 16 | 1 | 0.266 |
| Surgut | 61 15 | 73 30 | 1 | 0.259 |
| | | | 2 | 0.233 |
| | | | 3 | 0.209 |
| Sytomino | 61 17 | 71 18 | 1 | 0.259 |
| | | | 3 | 0.211 |
| Tobol'sk | 58 09 | 68 11 | 1 | 0.259 |
| | | | 2 | 0.247 |
| | | | 3 | 0.216 |
| Tommot | 58 58 | 126 19 | 1 | 0.194 |
| | | | 3 | 0.192 |
| Troitsk† | 54 06 | 61 35 | 1 | 0.252 |
| Troitsko-Pechorskoye | 62 42 | 56 12 | 1 | 0.244 |
| | | | 3 | 0.242 |
| Tugulym | 57 05 | 64 33 | 1 | 0.254 |
| Turukhansk | 65 49 | 87 59 | 1 | 0.254 |
| | | | 2 | 0.245 |
| | | | 3 | 0.240 |
| Tyumen' | 57 09 | 65 30 | 1 | 0.250 |
| | | | 2 | 0.240 |
| | | | 3 | 0.204 |
| Uglich | 57 32 | 38 19 | 1 | 0.290 |
| | | | 2 | 0.242 |
| | | | 3 | 0.238 |
| Ussuriysk | 43 48 | 131 59 | 1 | 0.243 |
| | | | 2 | 0.209 |
| Ust'-Kulom | 61 42 | 53 40 | 1 | 0.259 |
| Valday | 57 59 | 33 16 | 1 | 0.305 |
| Vereb'ye | 58 41 | 32 42 | 1 | 0.264 |
| | | | 3 | 0.242 |
| Vereshchagino† | 58 05 | 54 40 | 1 | 0.242 |
| | | | 2 | 0.238 |
| Verkhoyansk | 67 33 | 133 23 | 1 | 0.173 |
| Voznesen'ye | 61 01 | 35 29 | 1 | 0.242 |
| Vyazniki | 56 15 | 42 10 | 1 | 0.295 |
| Yakovlevka | 44 25 | 133 29 | 1 | 0.238 |
| | | | 3 | 0.206 |
| Yar-sale | 66 50 | 70 50 | 1 | 0.317 |
| Yessey | 68 29 | 102 10 | 1 | 0.226 |
| Zyryanka | 65 44 | 150 54 | 1 | 0.218 |
| | | | 3 | 0.211 |

* Data obtained from Soviet sources and adjusted by +20% (see text).
† Same station name given for two different locations (see Appendix C).

g/cm³ for November, December, January, February and March, respectively. Obviously the SCD of 0.18 g/cm³ for March was low, especially since 0.29 g/cm³ was observed in April as thawing began. The March value, consequently, was considered to be closer to 0.23 g/cm³ which increased the *unadjusted* average seasonal density at Chishmy to 0.210 instead of 0.200 g/cm³. Similar amendments were limited in number, and in almost all cases the average SCD did not change by more than ± 0.01 g/cm³.

The correction factor of plus 20%, and the few other minor adjustments, were then applied to the SCD's reported by the 105 Soviet stations and the results are shown in Table 1. The stations in the tabulation are listed alphabetically, with coordinates to the degree and nearest minute. Note also that many stations conducted density measurements in forest clearings and under forest canopies. These SCD values were adjusted in a similar fashion to those taken in the open field and included in Table 1. A comparison study between these SCD measurements made at locations of different exposure is presented later in *Seasonal, Monthly and Local Density Variations.*

## DEVELOPMENT OF THE SOVIET SNOW-COVER DENSITY CHART

### Previous work

One of the main objectives of this study was to construct a map that shows probable distribution of SCD across the Soviet Union. The idea evolved following the development of such a map for northern North America (Bilello 1967).

In the 1967 investigation, a relationship between climate and the regional variations in SCD was de-

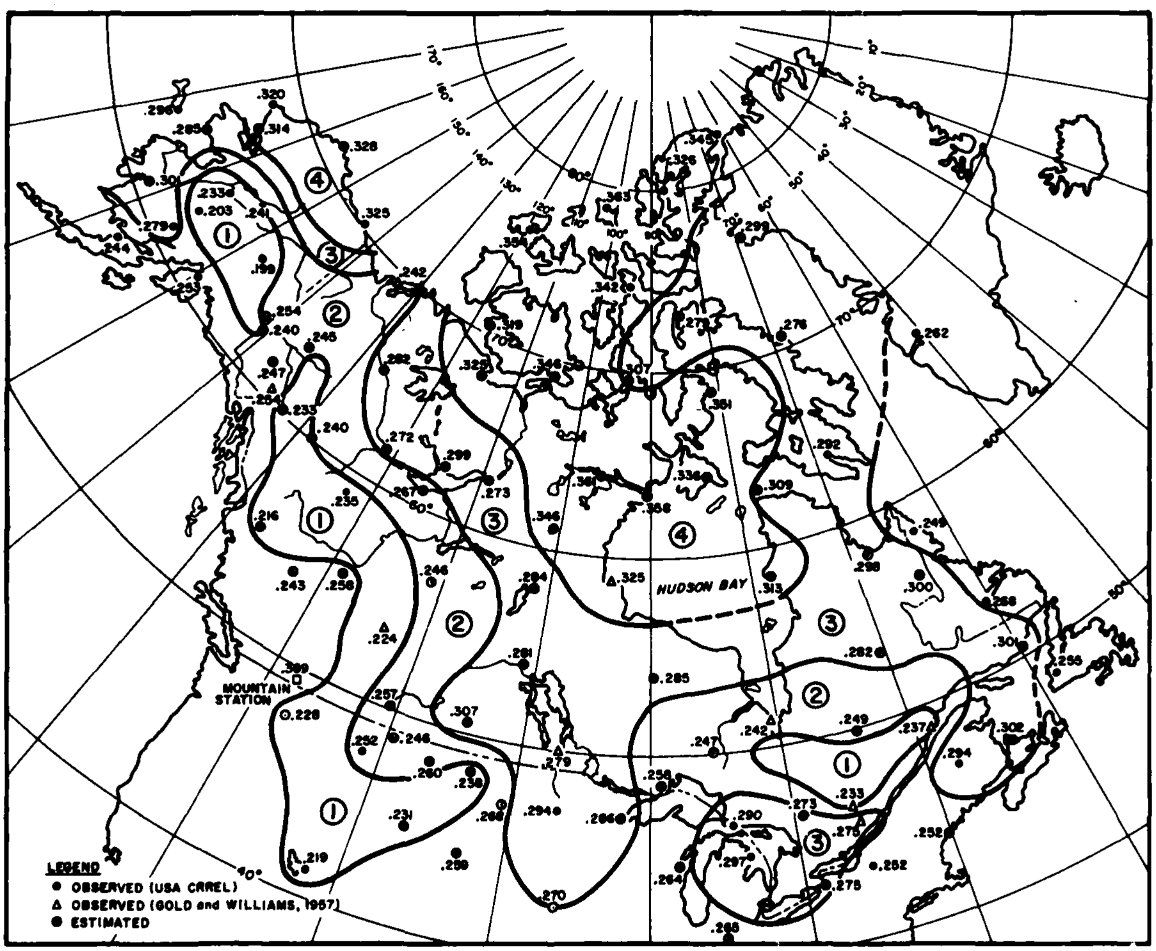



*Figure 1. Average seasonal snow-cover densities for northern North America. Categories 1-4 are separated at densities of 0.24, 0.27 and 0.31 g/cm³.*

veloped using data collected from a systematic observation program at stations in Canada, Alaska and the northern conterminous United States. The results of the study showed that the stations could be placed into one of four SCD categories. The density limits for these four categories were defined as $<0.24$ g/cm³ for category 1, $\geq 0.24$ to $<0.27$ g/cm³ for category 2, $\geq 0.27$ to $<0.31$ for category 3, and $\geq 0.31$ g/cm³ for category 4. These groupings were based on observed densities, climatic factors, and to some extent on geographic considerations. The main reason for the grouping concept is to emphasize that the study attempts to define regional variations rather than point estimates of SCD.

A multiple regression analysis in which seasonal SCD is related to concurrent air temperature and wind speed observations was also performed in the 1967 study. The resultant equation derived from 2500 density measurements obtained from 2 to 11 years of record at 27 stations was

$$\varrho = 0.152 - 0.0031T + 0.019W \quad (1)$$

where $\varrho$ = average seasonal SCD (g/cm³)
$T$ = average seasonal air temperature (°C)
$W$ = average seasonal wind speed (m/s).

The correlation coefficient and the error of estimate in the relationship were 0.84, and 0.025 g/cm³ respectively. Interestingly, the numerical constant (0.152) appearing in eq 1 is almost identical to that given by Dmitrieva (1950) for the average density of fresh snow (i.e. 0.15 g/cm³).

Climatological data for 61 other stations across northern North America were then compiled and average SCD values were estimated from the equation. These values, plus the data from the 27 basic stations and from 10 other locations given in Gold and Williams (1957), were used to draw an average SCD map for North America (Fig. 1). In this figure the densities across the continent are divided into the four categories described earlier and are separated at 0.24, 0.27 and 0.31 g/cm³.

**Relationship between Soviet climate and SCD regional variations**

A test was conducted to determine the possible application of eq 1 for developing the SCD map for the Soviet Union. In order to do this, air temperature and wind speed records were required for Soviet stations where SCD data were available. A comprehensive search and retrieval of monthly weather records for stations in the U.S.S.R. was therefore conducted. The required data consisted of long-term monthly summaries of observed air temperature and wind speed data for the period November through March. This portion of the winter was used so that the selected "seasonal" SCD period would be similar for both studies. The monthly climatic summaries were obtained from four principal sources: U.S. Air Force (1948-1971), U.S. Depa. .r:nt of Commerce (1951-1960), U.S. Air Force (1965-1968), and Nuttonson (1950).

Climatic information for over 500 stations in the U.S.S.R. was obtained from these sources, and used for various purposes in this report, including its possible use in the relationship given in eq 1. To test the relationship, 41 Soviet stations with available SCD information and corresponding air temperature and wind data were used in the analysis. The adjusted SCD values given in Table 1 were used in these tests. Unfortunately, the results revealed that eq 1 provided estimated Soviet densities for a majority of stations that could not be realistically accepted. Of the 28 stations used in the test, five estimated densities were low (by -1% to -6%), and one value matched exactly, but 22 estimates were much too high-ranging from +2% to +33%, with an average of +10%.

Since the climatic index of combined temperature and wind speed gave unsuitable Soviet SCD estimates, separate tests on each of the climatic parameters were conducted. When average seasonal air temperatures alone were used to estimate the densities, the correlation proved to be extremely poor. The scatter of points that evolved when the data sets were plotted indicated that further statistical evaluation in the relationship would be fruitless. This incompatibility in the temperature relationship between the two continents may partially result from greater length of the winter in the Soviet Union, especially in central Siberia, than across northern North America. The average seasonal (i.e. November through March) air temperatures between the two regions would not be similar and therefore not comparable.

The test on the relationship between average wind speed (for November through March) and the adjusted seasonal SCD for the Soviet locations proved, however, to be quite successful. Weinberg and Gorlenko (1940) also note that the densification effect by wind on the snow cover is of significant importance. Wind fragments the snow crystals, causes the finer grains to re-sort and increases the density of the snow cover by packing. Data sets for the 41 test stations are presented in Table 2, and plotted in Figure 2. The stations in

**Table 2. Average seasonal adjusted snow-cover density vs associated average seasonal (November through March) wind speed for 41 Soviet field sites.**

| Station* | Density category | Snow-cover density ($g/cm^3$) | Wind speed (m/s) |
|---|---|---|---|
| Oymyakon | 1A | 0.173 | 0.4 |
| Verkhoyansk | 1A | 0.173 | 0.6 |
| Krasnyy Chikoy | 1A | 0.192 | 1.0 |
| Kedon | 1A | 0.194 | 1.1 |
| Zyryanka | 1B | 0.218 | 2.0 |
| Blagoveshchensk | 1B | 0.218 | 2.8 |
| Kirovskiy | 1B | 0.221 | 2.0 |
| Yessey | 1B | 0.226 | 2.2 |
| Dzerzhinskoye | 1B | 0.230 | 2.3 |
| Saskylakh | 2 | 0.240 | 3.4 |
| Krasnoyarsk | 2 | 0.240 | 3.7 |
| Troitsko-Pechorskoye | 2 | 0.240 | 3.3 |
| Berezovo | 2 | 0.245 | 3.4 |
| Kolpashevo | 2 | 0.245 | 3.7 |
| Dolgiy Most | 2 | 0.250 | 2.4 |
| Tyumen' | 2 | 0.250 | 4.7 |
| Chelyabinsk | 2 | 0.252 | 4.2 |
| Kamenka | 2 | 0.254 | 2.4 |
| Turukhansk | 2 | 0.254 | 3.9 |
| Bakchar | 2 | 0.257 | 3.8 |
| Tobol'sk | 2 | 0.259 | 4.1 |
| Surgut | 2 | 0.259 | 4.7 |
| Kezhma | 2 | 0.262 | 2.5 |
| Kargasok | 2 | 0.262 | 4.3 |
| Leushi | 2 | 0.264 | 3.8 |
| Petropavlovsk | 2 | 0.264 | 5.2 |
| Sukhobuzimskoye | 2 | 0.266 | 3.4 |
| Aleksandrovskoye | 2 | 0.269 | 3.4 |
| Kurgan | 2 | 0.269 | 4.3 |
| Perm | 2 | 0.269 | 5.0 |
| Kazan' | 3 | 0.271 | 5.3 |
| Khoseda-Khard | 3 | 0.274 | 4.4 |
| Dudinka | 3 | 0.283 | 5.3 |
| Gor'kiy | 3 | 0.283 | 5.8 |
| Kustanay | 3 | 0.288 | 4.3 |
| Karaganda | 3 | 0.290 | 4.9 |
| Bogotol | 3 | 0.298 | 4.8 |
| Kokchetav | 3 | 0.298 | 5.8 |
| Saratov | 3 | 0.300 | 5.3 |
| Noril'sk | 3 | 0.300 | 6.1 |
| Novyy Port | 4 | 0.322 | 7.3 |

* Station coordinates and elevation (if available) are given in App. C.

Table 2 are listed according to increasing adjusted seasonal SCD starting with the lowest and ending with the highest value. This was done for two reasons: 1) to emphasize the marked association between increasing densities and increasing wind speeds, and 2) to show how groups of stations were placed within the density categories described earlier.

At this point, it should be noted that category 1 for the Soviet data was divided into two parts because 29 of the 105 Soviet field stations reported adjusted values of $<0.24$ $g/cm^3$ and almost half of these stations (13 out of 29) reported values less than 0.21 $g/cm^3$. Consequently category 1A contained values $<0.21$ $g/cm^3$ and category 1B included values $\geq 0.21$ to $<0.24$ $g/cm^3$. As will be

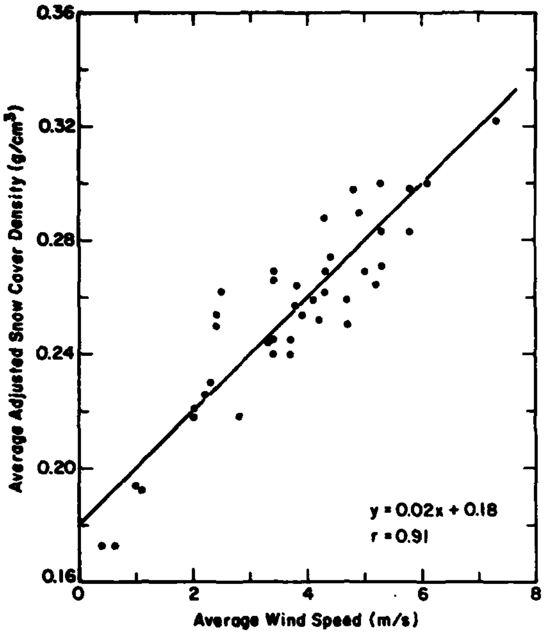



*Figure 2. Average five month (Nov–Mar) snow-cover density (g/cm³) (field site data-adjusted by +20%) vs average 5 month (Nov–Mar) observed wind speed records (m/s), for 41 field sites in the U.S.S.R.*

seen later, a major portion of the Soviet Union experiencing light winter winds is included in category 1A.

A regression analysis of the data shown in Figure 2 was conducted, and the resultant equation is

$$\varrho = 0.181 + 0.0197W$$

or

$$\varrho = 0.181 + 0.020W \qquad (2)$$

where $\varrho$ is the average seasonal SCD (adjusted by +20%) in grams per cubic centimeter and $W$ is the average seasonal (November through March) wind speed in meters per second. The correlation coefficient and the standard error of estimate in the relationship are 0.91 and 0.014 g/cm³ respectively.

## PREPARATION OF THE SNOW-DENSITY CHART

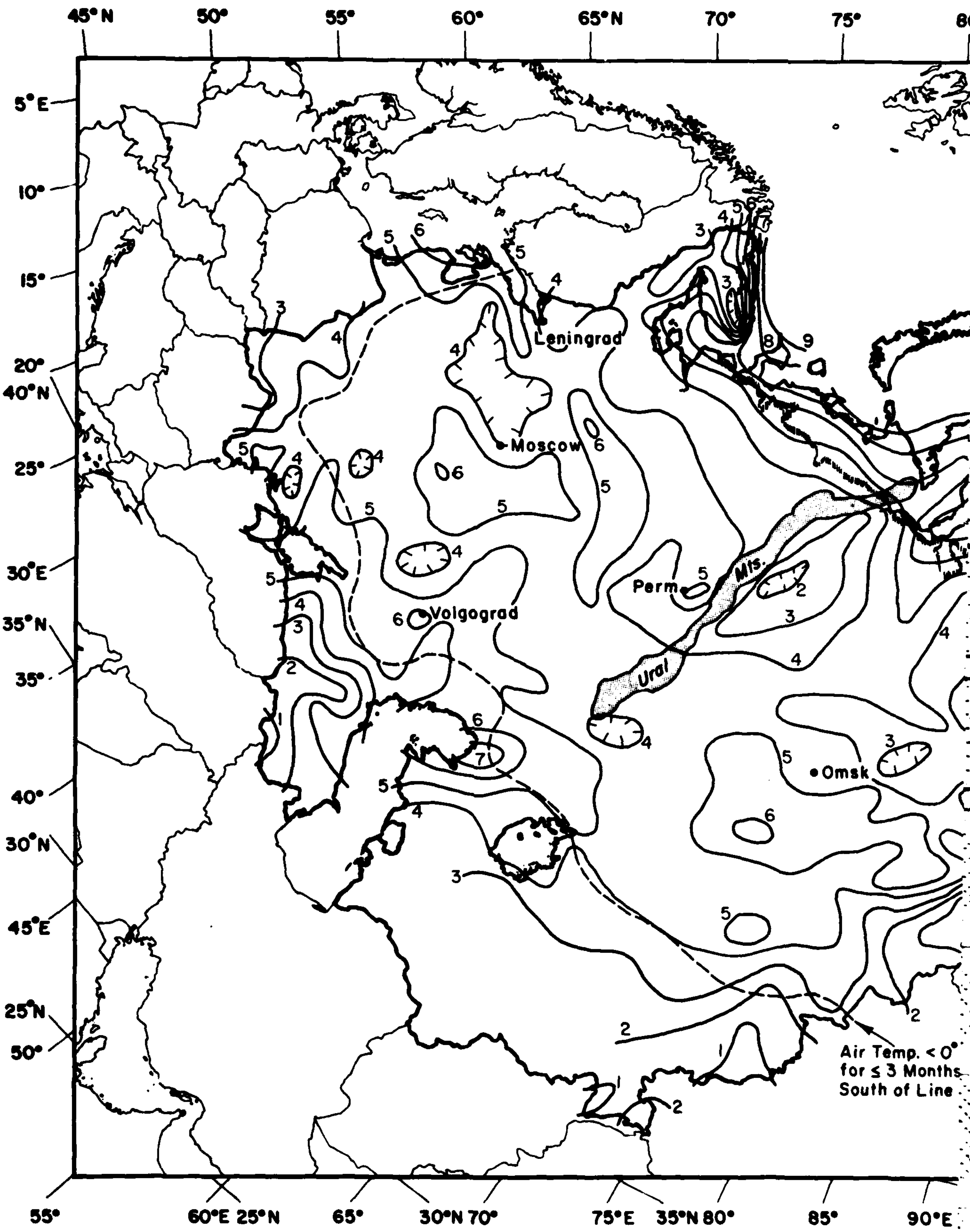
### Selection of base map for plotting purposes

The National Geographic Map of the Soviet Union (National Geographic Society 1976) provided excellent station location coverage, and its scale was sufficiently large to accomplish all the plotting requirements. The base chart drawn for this study was constructed from this map and included 1) U.S.S.R. boundary lines, 2) coordinate identifiers, 3) the location of "the northern limits of wooded country," and 4) the location of a few major cities. Other information such as the outline of the Ural mountains, and a line demarcating the region in southwest Russia that records average freezing air temperatures during three or less months of the year were obtained from the U.S. Army (1962 and 1964), and U.S. Air Force (1948–1971) respectively.

### Soviet snow-cover density chart

The initial step in the construction of a chart on the regional distribution of SCD across U.S.S.R. was to plot the adjusted densities determined for the 105 Soviet stations listed in Table 1 on the base map. Although the number of Soviet stations was almost three times as great as that available for the North American study (i.e. 37 sites), the coverage for the U.S.S.R. is still rather sparse. To supplement this primary data base, the relationship between wind speed and SCD shown in eq 2 was utilized. To accomplish this objective, average "seasonal" wind speed values for the more than 500 climatic stations (referred to earlier) across the Soviet Union were compiled (App. C). This alphabetical tabulation lists the station coordinates (to the degree and nearest minute), the average seasonal (November through March) wind speed to the nearest tenth (in meters per second), and if available, the station's elevation (meters above sea level), and the number of months per year with air temperatures of less than 0°C.

This information was then used to construct a wind chart for the Soviet Union based on average wind speed recorded from November through March (Fig. 3). Considerable confidence in the accuracy of this Soviet wind chart was gained because of the large number of data points available for the analysis. It was also noted that the average wind speed recorded during each of the months was generally quite uniform, so that the variability for this climatic parameter was minimal. Although Figure 3 was developed to provide additional guidance toward the construction of a SCD chart, it also presented some unusual Soviet wind speed conditions. For example, very strong wind speeds are observed along parts of the northern and eastern coasts of the U.S.S.R. The average mid-winter winds at some of these areas exceed 9 m/s. In contrast, very light winds of less than 2



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65°
30° N 70°
75° E
35° N 80°
85°
90° E
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Moscow
Volgograd
Perm
Ural
Mts.
Omsk
Air Temp. < 0° for ≤ 3 Months South of Line

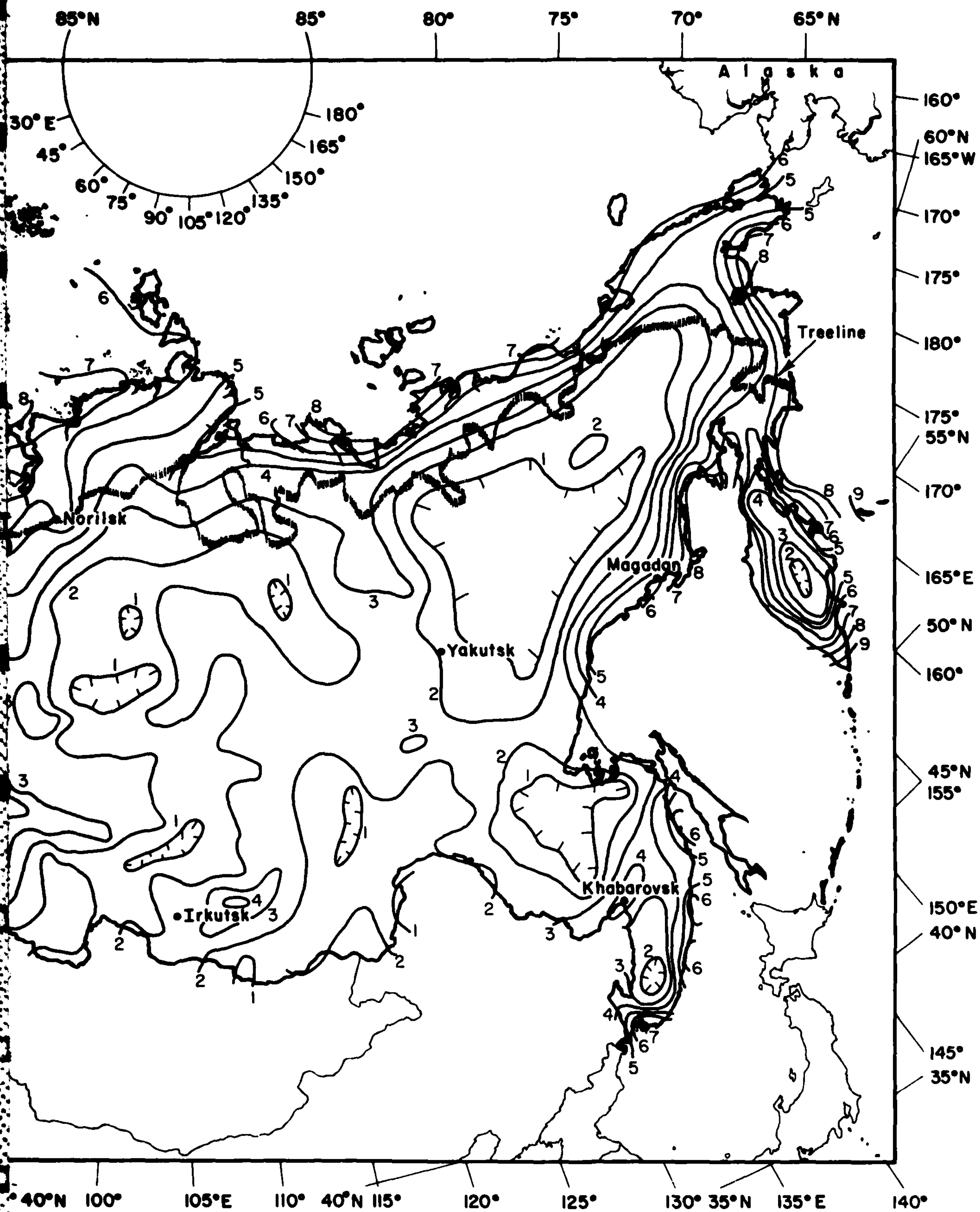
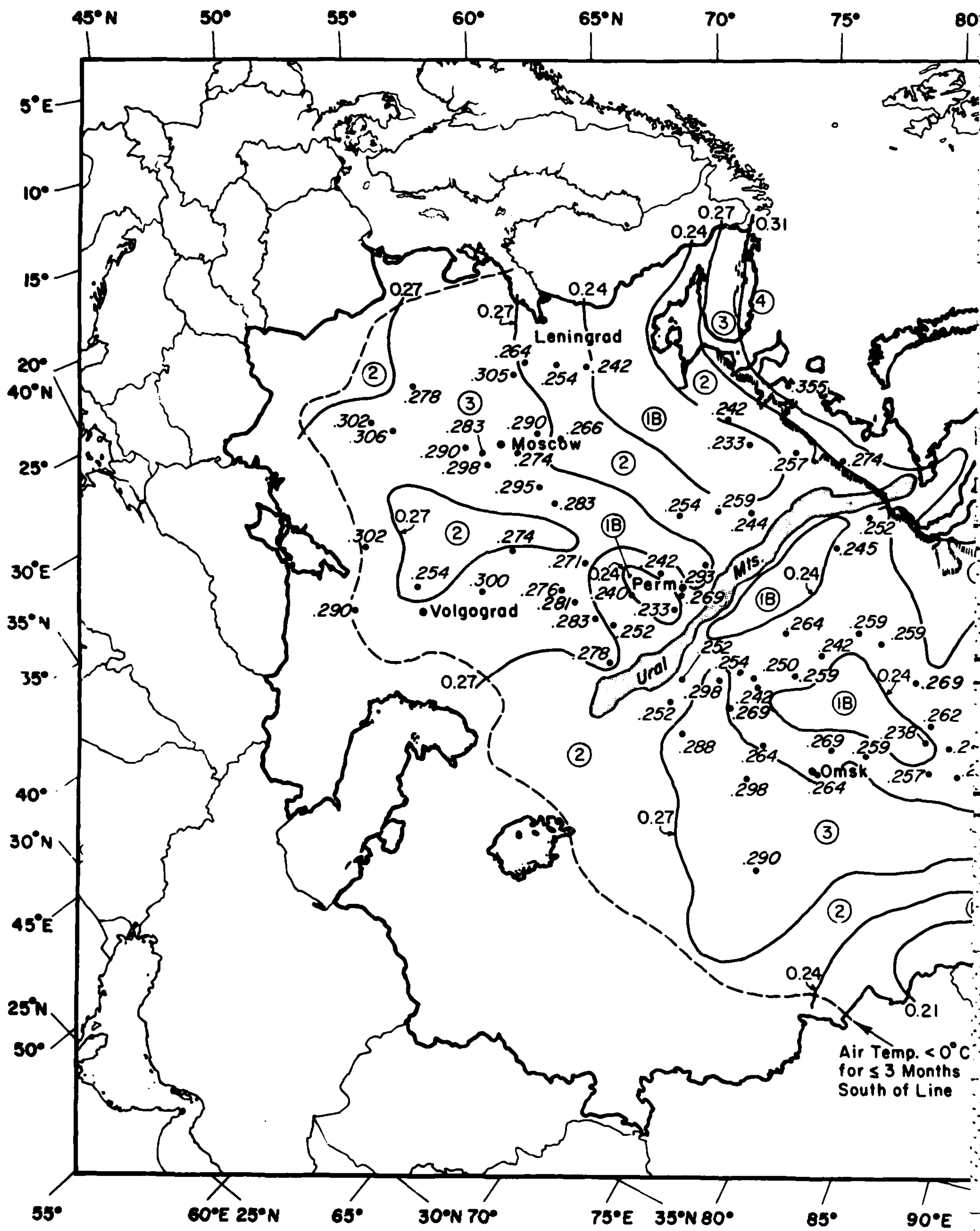



*Figure 3. Isolines of average winter (November–March) wind speed (m/s) for the U.S.S.R.*



Leningrad
Moscow
Perm
Volgograd
Omsk
Ural Mts.
Air Temp. < 0°C for ≤ 3 Months South of Line

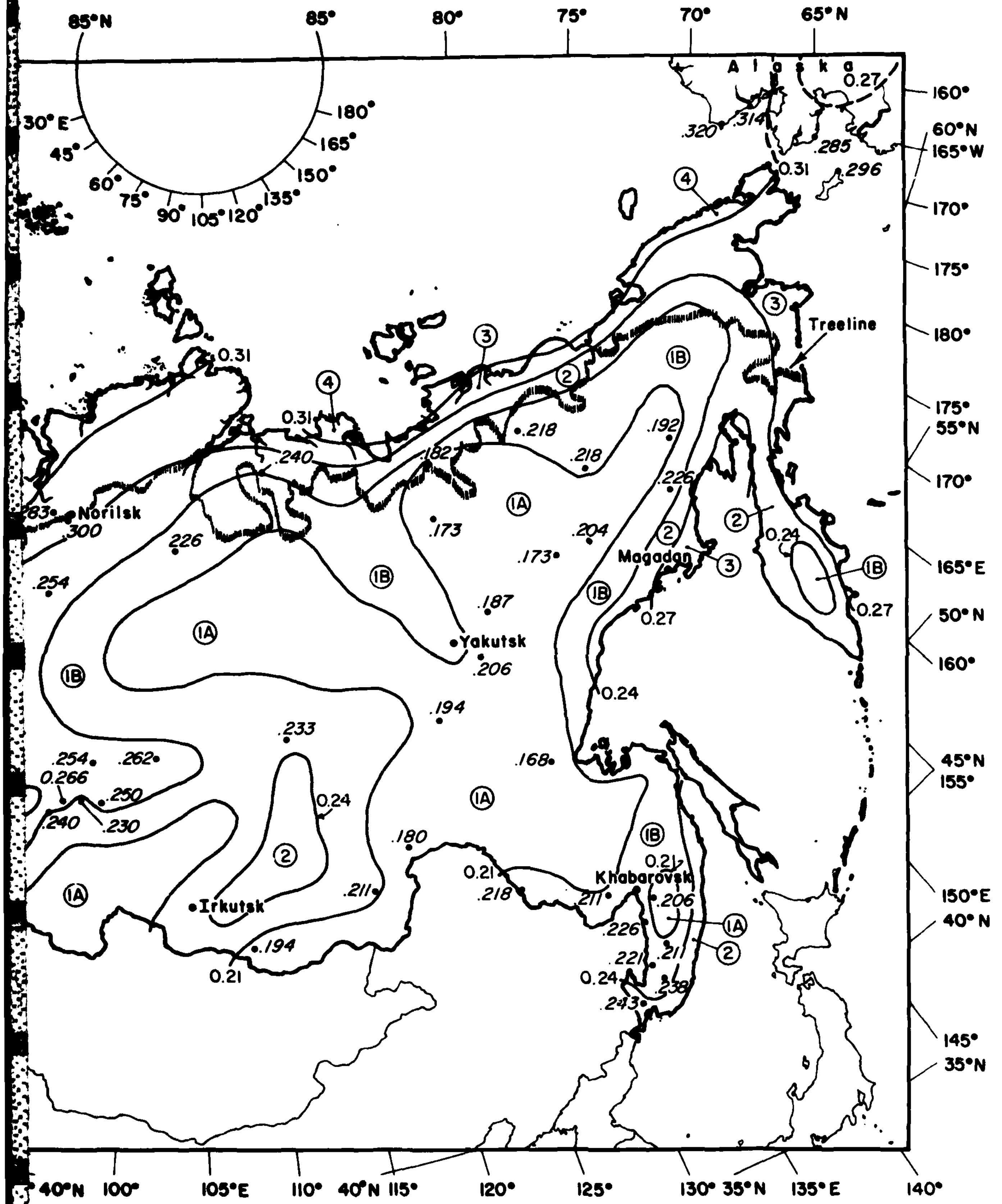



*Figure 4. Average seasonal snow-cover densities for the U.S.S.R. Categories 1A, 1B and 2–4 are separated at densities of 0.21, 0.24, 0.27 and 0.31 g/cm³.*

m/s on the average are recorded in winter throughout the interior region of eastern and central Siberia. Some regional wind speed differences due to land/water contrasts and mountain barriers (e.g. the Urals) were also noted.

The five SCD zones, separated at density values of 0.21, 0.24, 0.27 and 0.31 g/cm$^3$, correspond almost exactly with seasonal wind speeds of 1.5, 3.0, 4.5 and 6.5 m/s as shown in eq 2 and Figure 2. By using the position of the contours that locate these particular wind speeds, the isoline analysis presented in Figure 3 would therefore be useful in the development of the density chart.

The application of this relationship, in combination with the plot of the 105 adjusted SCD values, produced the final Soviet Union SCD map (Fig. 4). The country was divided into the five selected categories, ranging from the very light snow cover (category 1A) in the sheltered regions of central Siberia to densely packed snow (category 4) across most of the arctic coastline. In areas void of data points, the density boundaries were determined not only by wind speed but by other physical features such as topography and the northern limit of tree growth. Incidentally, no attempt was made to evaluate the variations in SCD that occur in mountainous regions. In fact, since all but 15 of the almost 350 stations that provided elevation data were located below 800 m, estimated SCD's for locations above this height should not be considered as applicable in this study.

Lipovskaya (1966) produced a chart that shows average density of snow cover for the Soviet Union (Fig. A2). This chart was prepared in accordance with the following quoted information:

> Multiyear data, as well as data calculated from annual observations based on snow surveys and constant snowstakes, served as the basic material for plotting the chart of density occurring in the decade of deepest snow.

The results shown in Figure A2 were not in any manner included in the analysis used in Figure 4. Nevertheless, some marked similarities and one major difference between the two SCD charts were found. For example, the regions of highest densities in both studies occurred along the northern fringes and eastern edges of the U.S.S.R. Very light snow covers were found in the eastern interior (Siberian) sections, and on the sheltered (eastern) side of the Ural Mountains. Considerable regional variations in density were also found in the western sections including the European portion of the country in both studies. The major (and important) difference in the studies is, however, the actual density values shown in the figures. It is apparent that Lipovskaya used snow survey data collected prior to 1966 when the densitometers in use were providing incorrect readings. Consequently, the SCD isolines shown in Figure A2 are generally about 20% lower than those described by the regional categories presented in Figure 4. Although the similarities in the general distribution of SCD throughout the nation in both (independently conducted) studies are noteworthy, the results provided in Figure 4 are believed to be more accurate.

## SEASONAL, MONTHLY, AND LOCAL DENSITY VARIATIONS

The information provided in Figure 4 can be considered limited in that it only provides average regional SCD values. Therefore three questions accompany the subsequent use of such data:

1. Within each of the selected categories, what range of SCD's would be expected when all the values observed throughout the period of record are considered?
2. What variations in SCD can be expected on a month-to-month basis within each of the categories?
3. What variations in SCD were observed in areas of different exposure?

Examination of the SCD data received from the 105 Soviet stations, and results obtained from the previous SCD study for North America provided additional information that address some of the relevant questions.

### Frequency distribution curves

Although a specific range in densities was selected to define each of the SCD categories, individual density measurements made from November through March would, of course, vary above and below the established limits. In order to show such a distribution of measurement points, a series of frequency curves based on all observed densities are required. Unfortunately, such curves could not be developed since only average monthly SCD values based on all the years of record are available for the Soviet data. A good indication of the probable distribution may, however, be derived from results obtained in the North American report (Bilello 1967). In that study, frequency distribution curves were developed for categories 1 through 4 (Fig. 5). Except for category 1, the SCD limits for the categories given in both studies are similar. The need to separate category 1 (Fig. 5) into 1A and 1B to conform with the Soviet classification in this case did not seem warranted. The

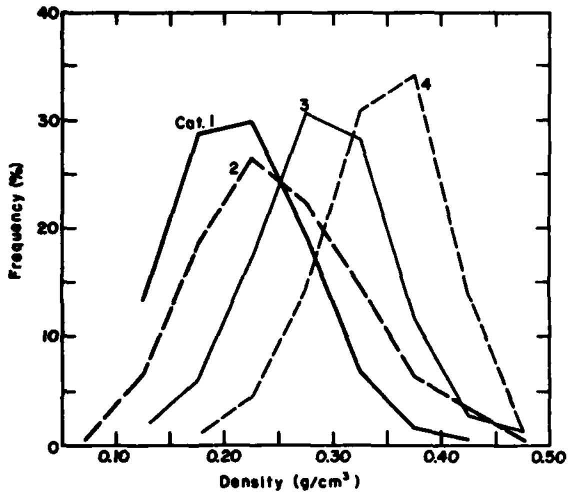



*Figure 5. Frequency curves for density categories 1–4. Curves comprise line segments connecting midpoints of class intervals 0.10–0.15 g/cm³, 0.15–0.20 g/cm³, etc. Curves refer to data obtained in North America study (Bilello 1967).*

distribution shown in category 1 for North America can instead be associated with the Soviet data in category 1B because the mean SCD value in these groups are quite close (i.e. 0.214 g/cm³ for North America, and 0.224 g/cm³ for the Soviet Union).

The frequency curves in Figure 5 show how each of the categories fall within a series of increasing densities. Naturally, the local topography and vegetation create differences in density from point to point within a categorically defined region. Deviations from any of the computed averages for each station can be expected from month to month and year to year. These distribution curves provide an indication of the extent of these areal, seasonal and annual variations in SCD.

**Monthly increase in density**

The metamorphic processes which take place within a snow cover with time have been described by a number of investigators (e.g. Bader et al. 1939, de Quervain 1945 and Kingery 1960). It has been shown (e.g., Shepelevsky 1938, Work 1948 and Gold 1958) that this aging process results in a gradual increase in the snow-cover density as the winter progresses.

This time-densification process was investigated using the average adjusted monthly density values available from the Soviet sources and compared with results obtained from the North American study. The monthly values for all stations within each of the categories were combined and the computed averages for both studies are presented in Table 3.

**Table 3. Comparison of average monthly snow-cover density (SCD) values (g/m³) between U.S.S.R and North American stations.**

| Category | *U.S.S.R. average adjusted SCD's* Nov | Dec | Jan | Feb | Mar |
|---|---|---|---|---|---|
| 1A | 160 | 176 | 186 | 202 | 220 |
| 1B | 191 | 206 | 221 | 234 | 269 |
| 2 | 215 | 238 | 255 | 268 | 296 |
| 3 | 223 | 252 | 288 | 314 | 356 |
| 4 | 288 | 308 | 340 | 356 | 364 |

| Category | *North American average SCD's* Nov | Dec | Jan | Feb | Mar |
|---|---|---|---|---|---|
| 1 | 179 | 197 | 212 | 234 | 237 |
| 2 | 238 | 226 | 254 | 263 | 280 |
| 3 | 268 | 277 | 291 | 294 | 311 |
| 4 | 317 | 343 | 342 | 348 | 345 |

The density for the Soviet stations in categories 1A, 1B, 2 and 3 (except from February to March for category 3) increases from about 0.15 to 0.20 g/cm³ each month, whereas the density for the North America stations in categories 1, 2 and 3 (except from November to January for category 2) increases by approximately 0.10 g/cm³ each month. The stations in category 4 in both regions show much less change throughout the winter. This uniformity may result because their densities are initially quite high, and because they are located at latitudes where the the effects derived from solar radiation toward snow-cover compaction during mid-winter are negligible.

**Density variations due to exposure**

Of the 105 Soviet stations that conducted SCD observation in open field areas (Table 1), 29 also made concurrent measurements in forest clearings (i.e. partially exposed areas), and 37 also made measurements under a forest canopy (i.e. protected areas). An inspection of the SCD variations that one might expect due to these environmental differences was made. The test was conducted by comparing each of the Soviet average seasonal adjusted *field* SCD's with 1) the associated value obtained at the forest clearing site, and 2) the associated value obtained under a forest canopy. Plots of these data sets are shown in Figures 6 and 7 respectively.

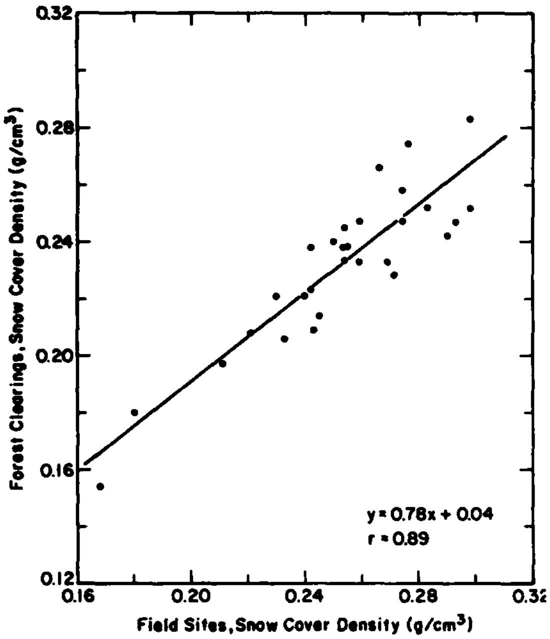



*Figure 6. Comparison of U.S.S.R. average seasonal adjusted snow-cover density (g/cm³) at open field sites vs at forest clearings.*

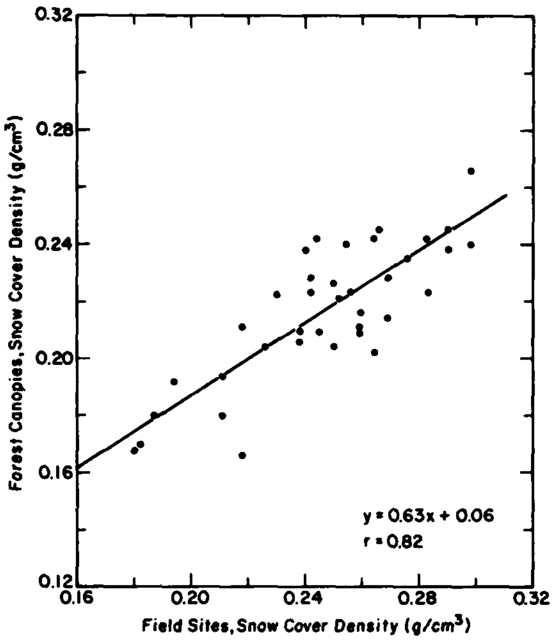



*Figure 7. Comparison of U.S.S.R. average seasonal adjusted snow-cover density (g/cm³) at open field sites vs under forest canopies.*

A line of best fit in both figures was determined in a regression analysis of the data points. The results presented in Figure 6 show that average seasonal SCD measurements made at forest clearings range from about 4% (for category 1A locations) to nearly 10% (for category 3 locations) *less* than those made in open field areas. The results in Figure 7 show that measurements made under a forest canopy range from about 8% (for category 1A locations) to near 14% (for category 3 locations) *less* than those made in open field areas.

## DISCUSSION

The results presented in this study provide an estimate of the average snow-cover density (SCD) regionally across the U.S.S.R. The study does not attempt to predict the density from point to point, from week to week or year to year. Included in the SCD map developed for the country were observed density values for 105 stations that were adjusted by +20%. This adjustment was based on recent Soviet literature that revealed systematic densitometer measurement errors resulting in low readings. This information, combined with a relationship found between wind speed and density, was then used to divide the U.S.S.R. into geographical areas that fall into one of five predefined ranges of density. Those regions with the least dense snow cover (<0.21 g/cm³) included the interior sections of the Soviet Union with light "winter" winds. The region with the greatest snow density (≥ 0.31 g/cm³) included the northern arctic coastal region and the northeastern fringe zones that are above the tree line. These areas are very exposed and subject to moderate to strong winds.

Within these regional ranges the snow cover and its characteristics can, however, be quite variable. Consequently, results of further studies on the subject provided some insight on the seasonal, monthly, and local variations that one might expect within the categories. For example, frequency deviations showed that, within each category, standard deviations (in density) of about ± 0.06 g/cm³ can be expected. Monthly SCD values were also found to increase gradually from November to March and were higher in open field areas than under a forest canopy. Attempts to evaluate the variations in SCD in mountainous regions were not made. Snowpacks in areas of complex terrain range from the permanent snowfields at higher elevations to an occasional, brief snow cover in the warmer valleys (Tsomaia 1956). Due to the relatively small scale of the snow-cover density base map and the limited number of observed data, further delineation of the selected categories

was not possible. In addition caution should be used when interpreting Figure 4 for regions above 800 m, since the vast majority of the Soviet stations with observed densities and/or wind speed data are located below this elevation. Nevertheless the results presented in this study would be applicable of areas where the topography, vegetation and wind speed are reasonably uniform.

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## APPENDIX A

## COMPILATION OF SNOW-COVER DENSITY INFORMATION EXTRACTED FROM VARIOUS SOVIET ARTICLES

In the review of the literature on snow cover characteristics, 28 Russian articles provided specific information on SCD in the Soviet Union. Some of these reports were previously available in English copy and the remaining papers were translated by CRREL. In some cases, the original articles were excessively lengthy and contained material irrelevant to this study. In these cases, only the pertinent sections of the articles were translated.

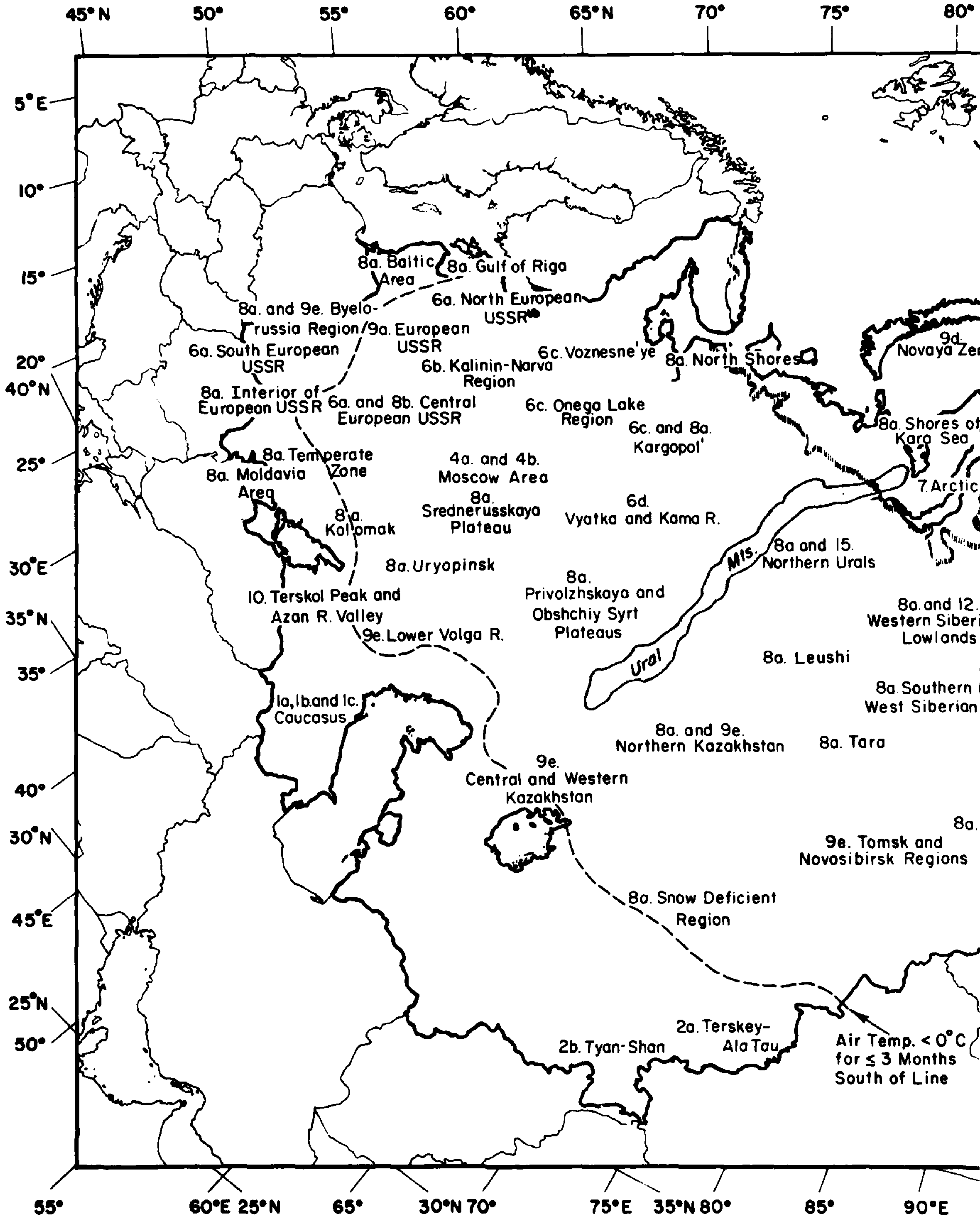
The snow density information that appeared germane to this report was extracted and included in this appendix. Although the bulk of the material was transcribed verbatim, numerous unnecessary sections, paragraphs, sentences, etc., were omitted from the original reports. Consequently, the listed summaries cannot be considered as fully completed quotations.

The information given in the 28 articles was placed into one of the following 15 general groups, most of which define geographical regions of the U.S.S.R.:

1. The Caucasus
2. Terskey - Ala Tau Mountain region
3. Southern part of the Buryat region
4. Moscow region
5. Amur Region
6. European part of the U.S.S.R.
7. Arctic Regions
8. Throughout the U.S.S.R.
9. Selected areas in the U.S.S.R.
10. Terskol Peak and Azau River Valley
11. Irkutsk
12. U.S.S.R. Taiga
13. U.S.S.R. Snow Surveys
14. Kamchatka
15. Ural Mountains

Some inconsistencies were noted in the articles. For example, the following statement is made in the Caucasus section (item 1a) "the conformity observed in the entire territory of snow cover density is lessening as the elevation above sea level increases." Whereas in the summary given under item 8a the statement, "In the mountains, it [i.e. snow-cover density] varies with the slope, orientation, snow-cover thickness and altitude above sea level. For example, the density increases in the Caucasian Mountains with altitude." Unless the statements are the results of incorrect translations, the observations are in direct conflict.

Despite the possible inherent erroneous information that may exist in the extracted material, excerpts of SCD values given in each of the articles were compiled and listed in Table A1. The general regions where these measurements were made are shown in Figure A1. This procedure makes it possible to associate the reported density values with the area to which they apply. Although the extracted SCD data cover many regions of the



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55°
60° E 25° N
65°
30° N 70°
75° E
35° N 80°
85°
90° E
8a. Baltic Area
8a. Gulf of Riga
6a. North European USSR
8a. and 9e. Byelo-russia Region
9a. European USSR
6a. South European USSR
6c. Voznesne'ye
8a. North Shores
9d. Novaya Zem
6b. Kalinin-Narva Region
8a. Interior of European USSR
6a. and 8b. Central European USSR
6c. Onega Lake Region
6c. and 8a. Kargopol'
8a. Shores of Kara Sea
8a. Temperate Zone
8a. Moldavia Area
4a. and 4b. Moscow Area
7. Arctic
8a. Srednerusskaya Plateau
8a. Kolomak
6d. Vyatka and Kama R.
8a. and 15. Northern Urals
Mts.
8a. Uryopinsk
8a. Privolzhskaya and Obshchiy Syrt Plateaus
10. Terskol Peak and Azan R. Valley
8a. and 12. Western Siberi Lowlands
9e. Lower Volga R.
Ural
8a. Leushi
8a Southern West Siberian
Ia, Ib and Ic. Caucasus
8a. and 9e. Northern Kazakhstan
8a. Tara
9e. Central and Western Kazakhstan
8a.
9e. Tomsk and Novosibirsk Regions
8a. Snow Deficient Region
2a. Terskey-Ala Tau
2b. Tyan-Shan
Air Temp. < 0°C for ≤ 3 Months South of Line

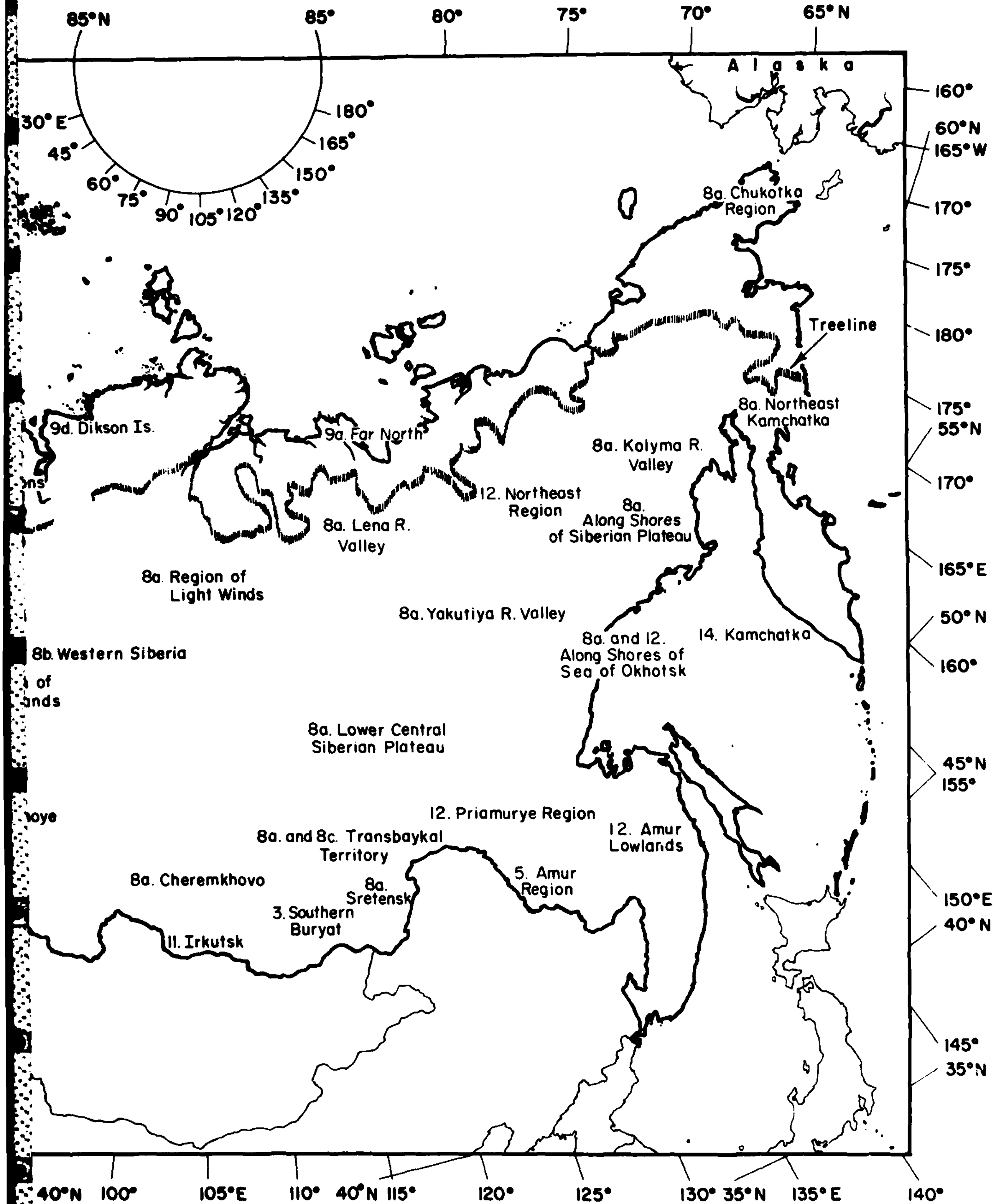


*Figure A1. Location of geographical areas (or regions) described in Appendix A (see Table A1).*

**Table A1. Summaries of snow-cover density data from 28 Soviet references. Numbers correspond to sections in this appendix and locations in Figure A1.**

*Excerpts of Snow-Cover Density Data from 28 Soviet References*

**1a, 1b and 1c. The Caucasus**
From 0.10 to 0.40 g/cm³ depending on month, elevation, slope, and exposure. Average value from November through April is less than 0.20 g/cm³. Density increases to 0.30 and 0.40 g/cm³ during thaw.

**2a. Terskey-Ala Tau**
Density increases from 0.20 to 0.25 g/cm³ between November and April.

**2b. Tyan-Shan**
During spring months, density ranges from 0.28 to 0.49 g/cm³.

**3. Southern Buryat**
During March 1956 density in steppes and forest-steppes was 0.13 to 0.20 g/cm³, with higher values (0.17 to 0.27 g/cm³) in drifted areas.

**4a and 4b. Moscow region**
Densities of 0.13 to 0.22 g/cm³ during November, and 0.15 to 0.20 g/cm³ in December. During thaw, values increase to between 0.22 and 0.34 g/cm³, and from 0.35 to 0.40 g/cm³ in drifts.

**5. Amur region**
Average seasonal densities of between 0.25 and 0.29 g/cm³. In March they range from 0.11 to 0.40 g/cm³.

**6a. South European U.S.S.R.**
At beginning of spring, thaw density is 0.22 or 0.23 g/cm³, but it is as high as 0.34 to 0.36 g/cm³ in open areas.

**6a. North European U.S.S.R.**
At beginning of spring thaw, density ranges from 0.22 to 0.28 g/cm³.

**6a and 8b. Central European U.S.S.R.**
At beginning of spring thaw, density ranges from 0.24 to 0.32 g/cm³. Values during March and April increase to 0.28 and 0.40 g/cm³.

**6b. Kalinin–Narva Region**
At the time of maximum water equivalent density ranges from 0.22 to 0.28 g/cm³.

**6c. Onega Lake Region**
Density in January is 0.20 to 0.28 g/cm³, and increases to 0.38 by April.

**6c and 8a. Kargopol'**
From November through March, density ranges from 0.13 to 0.26 g/cm³, with average values of 0.22 in open areas and 0.21 g/cm³ in protected areas.

**6d. Vyatka and Kama Rivers**
At time of maximum equivalent, density ranges from 0.26 to 0.32 g/cm³ in field areas, and 0.24 to 0.28 in forests.

**7. Arctic regions**
Density averages 0.30 to 0.35 g/cm³ all winter. It increases to 0.40 and 0.45 g/cm³ at the beginning of thaw.

**8a. Baltic region**
Average density less than 0.24 g/cm³.

**8a and 9e. Byelorussia region**
Average density is less than 0.24 g/cm³. In forests it ranges from 0.19 to 0.22 g/cm³, and in fields it reaches 0.25 g/cm³.

**8a. Interior of European U.S.S.R.**
Average density mostly near 0.24 g/cm³.

**8a. Temperate zone**
Density in forested areas 0.20 to 0.23 g/cm³, and 0.25 to 0.27 g/cm³ in unshielded areas.

**8a. Moldavia region**
Average density less than 0.24 g/cm³.

**8a. Kolomak**
Average density of 0.26 g/cm³ in both open and protected areas.

**Srednerusskaya Plateau**
Average density of 0.28 g/cm³.

**8a. Uryopinsk**
Average density of 0.27 and 0.28 g/cm³ in both open and protected areas.

**8a. Privolzhskaya and Obshchiy Syrt Plateaus**
Average density of 0.28 g/cm³ with lower values in the river valleys.

**8a and 9e. Northern Kazakhstan**
At higher elevations density ranged between 0.27 and 0.30 g/cm³.

**8a. Snow-deficient region**
Density ranges from 0.14 to 0.16 g/cm³.

**8a. North shores**
Average density is 0.30 g/cm³.

**8a and 15. Northern Urals**
Average density exceeds 0.28 g/cm³, and reaches 0.35 and 0.42 g/cm³ in second half of winter. In forest zones values range from 0.25 to 0.30 g/cm³ in upper third of snow pack and 0.15 to 0.28 g/cm³ in lower layers. In unforested zones wind slab densities are 0.42 to 0.45 g/cm³.

**8a. Leushi**
Average density of 0.22 g/cm³ in open areas, and 0.19 in protected areas.

**8a. Tara**
Average density of 0.28 g/cm³ in open areas and 0.26 in protected areas.

**8a. Shores of Kara Sea**
Average density of 0.30 g/cm³.

**8a and 12. Western Siberia Lowlands**
Density ranges from 0.19 to 0.25 g/cm³.

**8a. Southern Regions of West Siberian Lowlands**
Average density of 0.23 g/cm³.

**8a. Bolotnoye**
Average density of 0.25 g/cm³ in open areas and 0.21 in protected areas.

**8a. Region of light winds**
Average density of 0.22 g/cm³.

Table A1 (cont'd).

**8a. Cheremkhovo**
Average density of 0.20 g/cm³ in open areas and 0.18 in protected areas.

**8a. Lena River Valley**
Average density of 0.14 to 0.16 g/cm³.

**8a. Yakutiya River valley**
Average density of 0.20 g/cm³.

**8a. Lower central Siberian Plateau**
Density varies from 0.18 to 0.20 g/cm³.

**8a and 8c. Transbaykal Territory**
Average density ranges from 0.14 to 0.18 g/cm³.

**8a. Sretensk**
Average density of 0.16 g/cm³ in open areas, and 0.14 in protected areas.

**8a. Kolyma River Valley**
Average density of 0.20 g/cm³, ranges from 0.14 to 0.26 prior to spring melt.

**Along shores of Siberian Plateau**
Average density of 0.28 g/cm³.

**8a and 12. Along shores of Se of Okhotsk**
Density ranges from 0.19 to 0.25 g/cm³.

**8a. Chukotka region**
Average density of 0.30 g/cm³.

**8a. Northeast Kamchatka**
Densities of up to 0.36 g/cm³ along the coast.

**8a. Western Siberia**
Average densities of 0.19 to 0.22 g/cm³ in forest zones, and 0.22 to 0.31 g/cm³ in forest-steppe and steppe regions.

**9a. European U.S.S.R.**
Density ranges from 0.20 to 0.28 g/cm³ in January, and 0.28 to 0.30 g/cm³ in March.

**9a. Far North**
Density ranges from 0.20 to 0.25 g/cm³ in November, and 0.30 to 0.33 in March.

**9d. Novaya Zemlya**
On the east coast density is 0.28 to 0.35 g/cm³ in January and up to 0.39 in May. On the west coast the wind is not as strong and density in March is not greater than 0.27 to 0.30 g/cm³.

**9d. Dikson Island**
Density in the spring was 0.38 g/cm³.

**9e. Lower Volga River**
Density range at end of February is 0.23 to 0.32 g/cm³, increasing to 0.40 during thaw.

**9e. Central and Western Kazakhstan**
Density at the time of maximum snow deptt ranged from 0.30 to 0.35 g/cm³.

**10. Terskol Peak and Asau River Valley**
Snow cover with five layers: Top layer hoar frost density is 0.27 g/cm³, next lower layer consisted of fine-grained snow, next layer was packed snow at 0.40 g/cm³, next layer fine-grained at 0.33 g/cm³, and bottom layer was hoar frost.

**11. Irkutsk**
Average of three winter snow covers with three layers. Density of top 5 cm was 0.141 g/cm³, density of middle 5 cm was 0.214 g/cm³, and density of lowest 10 cm was 0.226 g/cm³.

**12. Priamurye region**
Density by the end of winter increased from between 0.13 and 0.15 g/cm³ to between 0.18 and 0.20 g/cm³.

**12. Amur Lowlands**
Density ranges from 0.19 to 0.25 g/cm³.

**12. Northeast region**
Density by the end of winter increases from 0.15 to 0.20 g/cm³.

**14. Kamchatka**
Density dependent on time of year, exposure, topography and snow depth. It ranges from 0.10 g/cm³ in October and November, to > 0.34 at maximum snow depth. Values are lower in interior sheltered areas and highest along coast and windy areas.

U.S.S.R., the heaviest concentration of information appears in the western (i.e. European) part of the country. Since Appendix A was included mainly for informational purposes, additional attempts to analyze the material were beyond the scope of the report.

## 1. THE CAUCASUS.

### 1a. Gurtovaya, Sulakvelidze, and Yashina (1960).

The average density of the snow cover [in this mountain region] from November to April is less than 0.20 g/cm$^3$, and in areas sheltered from the wind it generally is not more than 0.10-0.15 g/cm$^3$; the lowest density is found in February. Beginning with the end of April, the density of the snow cover, resulting from the thawing brought about by solar radiation, increases and by August reaches 0.35-0.40 g/cm$^3$ at the lower boundaries and at the upper boundaries it is less than 0.30 g/cm$^3$.

Because of the great variations in elevation and the physico-geographic variations in the area of the Caucasus, the snow cover density is very variable. It is first of all necessary to mention the conformity observed in the entire territory of snow cover density lessening as the elevation above sea level increases. Thus, from 0.40 g/cm$^3$ at a 1000 m elevation, it decreases to 0.15-0.20 g/cm$^3$ at the 3000 m elevation (February-March). In February-March, snow cover density of 0.30-0.40 g/cm$^3$ is characteristic for the Western Caucasus. It is not constant, however, and changes within a great range depending on the meteorological conditions and the slope exposures. On the northern slopes, the snow cover density for practically the entire winter is, as a rule 0.05-0.15 g/cm$^3$, which is below that of the southern slopes. At the beginning of the thaw and with clear weather, the difference in the snow cover density of these slopes may reach 0.20 g/cm$^3$. A noticeable increase in density occurs uniformly on all slopes during wet snow falls and advective heating.

DISTRIBUTION OF SNOW COVER DENSITY (in g/cm$^3$) IN THE WESTERN CAUCASUS

| Elevation above sea level, in m | Months | |
|---|---|---|
| | Dec-Jan, | Jan-Mar |
| 2800 | 0.18-0.20 | 0.28-0.30 |
| 2300 | 0.21 | 0.33 |
| 2000 | 0.22 | 0.35 |
| 1700 | 0.23 | 0.34 |
| 1500 | 0.25-0.28 | 0.35-0.37 |
| 1000 | 0.30 | 0.40 |
| 500 | 0.35 | 0.40 |

According to the information of snow measuring surveys in the basins of the Bzipi, Koderi, Inguri, and Riono Rivers, a sufficiently clear conformity was developed for the change in density by time and elevation. The density of the snow cover decreases from 0.30 g/cm$^3$ at an elevation of 1000 m, to 0.18 g/cm$^3$ at an elevation of 2800 m, and [increases] from 0.30 g/cm$^3$ in December-January to 0.40 g/cm$^3$ in February-March. Snow density action is particularly evident during the spring months. In March, the density of the snow at the upper levels of this zone is on the average 0.10-0.12 g/cm$^3$ higher than in December. In the lower belts of mountains, this difference decreases to 0.05-0.10 g/cm$^3$.

In the eastern Priel'brus area the most characteristic density during the winter at the bottom of the Bakaan River Valley is 0.25 g/cm$^3$ which decreases quite a bit during snow fall because of the freshly fallen snow. At the end of March and beginning of April, in the period of snow thaw, the density of the snow cover [increases] to 0.35 g/cm$^3$. The difference in snow cover densities between the northern and southern slopes is [evident]. In January, the density of the snow, because of the great insolation on the southern slope, is 0.07 g/cm$^3$ greater than on the northern, while in March, it is 0.09 g/cm$^3$ greater. The density of the snow at the bottom of the valley has an [uniform] value in comparison with its densities on the northern and southern slopes.

The given values of snow cover density are averaged values for these regions. A detailed snow measuring survey provides considerable differences in its density because of the character of the vegetative cover and the microclimatic conditions. The density of the snow is usually less in the forest than on open areas. A certain increase in snow cover density is observed on the windward slopes because of its packing by the wind and wind-blown snow.

DISTRIBUTION OF SNOW COVER DENSITY (in g/cm$^3$) IN THE CENTRAL CAUCASUS

| Elevation above sea level, in m | Months | |
|---|---|---|
| | Dec-Jan | Feb-Mar |
| 3000 | 0.18 | 0.21 |
| 2500 | 0.20 | 0.21-0.28 |
| 2200 | 0.26 | 0.25-0.30 |
| 2000 | 0.24-0.26 | 0.31 |

An example of the clearest differentiation of the snow thickness on the stratigraphic line may be that of the following description on the snow cover in the upper reaches of the Baksanskiy ravine (Central Caucasus) during the middle of February 1957. At an average snow cover thickness of 45-50 cm, the uppermost 0-5 cm were presented as newly fallen, friable, snow consisting of fragments of flakes (density 0.10-0.15 g/cm$^3$); lower, at a depth of 5-25 cm, there was deposited a firm, dense wind-blown slab (density of 0.36-0.40 g/cm$^3$) of small-grain snow. The thickness of the wind-blown slab varied from 10 to 25 cm. At a depth of 25-50 cm, was a line of friable plutonic hoarfrost. The plutonic hoarfrost crystals were large (5-7 mm), prismatic, hollow inside, and vertically oriented. They were solidly connected into clusters. The vertical texture with suspended clusters of crystals and a large amount of space between them was depicted very clearly. Lower, at the edge of the grass cover, the crystals were larger (to 10 mm), and the amount of volume of the space increased. The solidly frozen together crystals abutted with grains and gradually assumed a cylindrical form and horizontal orientation. The porosity of the lower line was so great that the frozen together crystals gave the impression of a porous screen; the ground was thawed.

Changes in the density of the snow thickness by the structural lines in forested and in open areas take place dissimilarly. In non-forested sectors, the upper line of the snow cover has a relatively larger density (0.21-0.28 g/cm$^3$) than the lower (0.15-0.23 g/cm$^3$) because of solidifying by wind and radiational heating. In the forested sectors, because of sheltering of the line by the crowns of trees, there is no solidifying of the upper line. Therefore, in the shaded sectors of the forest, one observes stages in the distribution character of the density along the profile of the snow thickness - namely, the development of density from the upper lines to the middle and its decreases in the line of friable plutonic hoarfrost.

1b. Glazyrin and Denisov (1967). Snow cover density measurements made during one winter at a meteorological station situated on the Krestoviy pass in the Caucasus ranged from 0.18 to 0.26 g/cm$^3$ during January through mid-March, and from 0.28 to 0.43 g/cm$^3$ during late March through April.

1c. Zal'ikhanov (1967). In this article the distribution of precipitation in the mountainous regions of the Karbardino-Balkaria ASSR is analyzed in terms of seasons and altitude zones. It is shown that complex orography, a great range of altitudes above sea level, and proximity to the Black Sea create a complex picture of precipitation distribution. On the basis of analysis of snow-measuring surveys, it is demonstrated that a zone of great snowiness is located just 0.6-1.1 km to the north of the Primary Divide at an altitude of 2900-3200 m. These data differ considerably from the figures obtained previously by a number of researchers.

According to the data of G.K. Sulakv'el'idze, from November until April the average snow density in a zone of stable snow cover is below 0.2 g/cm$^3$, and 0.10-0.15 g/cm$^3$ in areas protected from wind. According to measurements conducted by us in April, 1964, the average density in open areas in a zone of constant snow cover is 0.20-0.25 g/cm$^3$.

When snow falls on a surface of frozen earth, the contact of the snow cover with the surface of the earth is usually tenuous, which is conducive to movement of the snow on the surface of slopes, i.e., to the formation of avalanches.

The descent of a snow avalanche is importantly affected by the density of the snow. In studying the dependence of snow density on the elevation of the locality, the following features are noted:

(1) the density of snow cover decreases with an increase in absolute elevation of the locality. This is attributable to a decrease in the rapidity of the thawing process with increasing elevation.

(2) for the 2000-3000 m elevation zone, density of the snow cover, according to our data, is distributed with respect to the time of year in the following manner: when the snow falls, its density varies within the limits 0.10-0.20 g/cm$^3$; in the first half of the winter, when the air temperature is relatively high, the snow condenses, and its density reaches 0.30 g/cm$^3$. In open areas wind contributes to snow compaction;

(3) in February, as a result of large snowfalls the average density of snow cover again falls, reaching 0.20 g/cm$^3$;

(4) in the spring, during the initial thawing of the snow cover, the snow density reaches its maximal value of 0.40-0.45 g/cm$^3$. This density is apparently attributable to the fact that the water formed during the initial thawing does not reach the surface of the soil, but freezes in the snow mass, which leads to an increase in its density during the spring period;

(5) in April the density of the snow again declines to 0.30-0.40 g/cm$^3$. This may be explained by the fact that thawing takes place very rapidly as a result of high, positive air temperatures, and the water flows away. Values for elevation and density of snow-cover measured during a 1964 expedition are presented in the following table. [Table A2].

Table A2. Elevation and density of snow cover in April, 1964, in the territory of Kabardino-Balkaria.

| Elevation (m) | Adyl-Su Depth of snow cover* (cm) | Adyl-Su Snow density ($g/cm^3$) | Adry-Su Depth of snow cover (cm) | Adry-Su Snow density ($g/cm^3$) | Bashil'-Auzu-Su Depth of snow cover (cm) | Bashil'-Auzu-Su Snow density ($g/cm^3$) | Gara-Auzu-Su Depth of snow cover (cm) | Gara-Auzu-Su Snow density ($g/cm^3$) | Cherek-Bizengi Depth of snow cover (cm) | Cherek-Bizengi Snow density ($g/cm^3$) | Karasu-Balgarian (L'kezi) Depth of snow cover (cm) | Karasu-Balgarian (L'kezi) Snow density ($g/cm^3$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2200 | 6 | 0.38 | 8 | 0.36 | 16 | 0.34 | 8 | 0.34 | 12 | 0.32 | 16 | 0.31 |
| 2300 | 12 | 0.37 | 13 | 0.36 | 30 | 0.27 | 44 | 0.31 | 15 | 0.33 | 18 | 0.32 |
| 2400 | 28 | 0.36 | 18 | 0.36 | 46 | 0.30 | 108 | 0.30 | 17 | 0.29 | 12 | 0.31 |
| | 30 | 0.36 | 16 | 0.35 | 52 | 0.34 | 51 | 0.29 | 16 | 0.28 | 17 | 0.33 |
| 2500 | 38 | 0.37 | 14 | 0.36 | 34 | 0.30 | 64 | 0.30 | 17 | 0.26 | 19 | 0.35 |
| 2600 | 36 | 0.34 | 25 | 0.35 | 30 | 0.29 | 69 | 0.29 | 20 | 0.27 | 24 | 0.34 |
| 2700 | 39 | 0.32 | 36 | 0.34 | 32 | 0.28 | 71 | 0.26 | 22 | 0.22 | 23 | 0.30 |
| 2800 | 42 | 0.30 | 37 | 0.32 | 37 | 0.26 | 90 | 0.27 | 27 | 0.26 | 27 | 0.29 |
| 2900 | 46 | 0.29 | 40 | 0.31 | 37 | 0.21 | 170 | 0.28 | 30 | 0.26 | 31 | 0.26 |
| 3000 | 42 | 0.27 | 42 | 0.30 | 42 | 0.24 | 146 | 0.27 | 32 | 0.25 | 30 | 0.21 |
| 3100 | 40 | 0.26 | 44 | 0.28 | 42 | 0.23 | 139 | 0.26 | 42 | 0.26 | 26 | 0.22 |
| 3200 | 36 | 0.26 | 43 | 0.27 | 46 | 0.24 | 141 | 0.28 | 49 | 0.24 | 20 | 0.21 |
| 3300 | 34 | 0.21 | 42 | 0.27 | 15 | 0.23 | 149 | 0.27 | 34 | 0.21 | 29 | 0.21 |
| 3400 | - | - | - | - | 21 | 0.21 | 120 | 0.20 | 22 | 0.20 | - | - |
| 3500 | - | - | - | - | 19 | 0.11 | 107 | 0.15 | 19 | 0.20 | - | - |

*The depth of snow cover in each valley increases with an increase in the absolute elevation of the locality up to a certain elevation limit, and then it begins to decrease.

## 2. TERSKEY - ALA TAU MOUNTAIN REGION

2a. Iveronova (1960). The snow cover density during the winter has a clearly defined course. In the period of the fall "striated" landscape, there occurs a significant growth in the snow cover density; it changes little from December through February (the absolute value about 0.20 g/cm$^3$); it [increases] again strongly in March and reaches a maximum in April at the height of thawing. The density of the snow during the winter (November-March) at an elevation of 3250 m, close to the end of Karabatkak Glacier in a valley bottom (low grass alpine meadow), varies in insignificant limits (on the average, 0.20-0.22 g/cm$^3$). It begins to [increase] in April and reaches its maximum [density] during the height of the thaw - in May.

The density of the snow cover during the period of its continuous deposit has a rather clearly defined course: in the fall, in September-October, it increases, by November or December it generally falls a bit and then until May, to April in some years, it remains rather constant varying in small limits and on the average reaches rather large absolute values (0.23-0.25 g/cm$^3$). In May (or in April) the density of the snow begins to increase sharply and reaches a maximum at the height of thawing, in July, and occasionally in June.

2b. Sadvakasov and Kozik (1970). In the western spurs of the Tyan'-Shan' Mountains, we find the Kyzylcha River, forming a tributary of the second order to the Akhangaran (Angren) River. The Kyzylcha Basin has an area of 53.4 km$^2$; the height of its individual parts will fluctuate from 1200 to 3800 m above sea level; for more than 15 years, snow surveys have been conducted in the basin at permanent snow-measuring points during the cold season. In 1958 in the basin's center at a height of 2075 m, we established the Kyzylcha Snow-Avalanche Station. With its organization, the snow surveys became more regular and detailed; specifically, fairly detailed spring snow surveys from March to April were initiated in the basin of a ravine with an area of 0.21 km$^2$, specially chosen for water balance observations. The elevation mark of the ravine floor was about 2000 m above sea level, with average height of watershed relative to the closing line of the ravine amounting to 192 m. The meteorological site of Kyzylcha Station is located about 1 km from the ravine and is separated from it by a water divide occurring approximately at the station's altitude.

The snow survey data for six spring periods from 1960-1965 [were reviewed]. In the snow surveys, it was customary to take measurements of the depth and water content of the snow cover in several high zones based on horizontal traverse routes, tied into the terrain by permanent rods. The snow surveys were started in March at the beginning of the spring snow thawing and were ended when more than 90% of the ravine's surface had become free of snow. This usually occurred in April, rarely in May. The time spans between successive snow surveys usually comprised 1-3 days. Depth of snow in the traverse routes was determined approximately every 20 m while water content was estimated every 100 m. During the 6 years

indicated, data from 74 snow surveys were examined. Based on the data for each snow survey, the density value for the snow cover in the ravine during these spring months ranged from a minimum of 0.28 to a maximum of 0.49 g/cm$^3$. The average density observed was about 0.38 g/cm$^3$.

3. SOUTHERN PART OF THE BURYAT REGION.

Nefed'yeva (1960). The density of the Zabaykal'ya and [Gusino Lake depression] snow covers is comparatively low (0.15-0.18, rarely 0.20). It changes little during the course of the winter which is explained by the stable frosts, infrequent snow storms, and lack of thaw. By the end of March in 1956, in the majority of the steppes and forest-steppe regions of the Buryat, the snow density was 0.13-0.20. Direct observations have shown that in the open steppe regions, the snow cover, in spite of the low average density, is distinguished by rather uneven depositing explained by the wind redistribution of the snow.... The amount of water reserve in the wind blown snow drifts increases in comparison with the average by 5-10 times and the snow density increases by 30 to 35 percent.

4. MOSCOW AREA.

4a. Nefed'yeva (1960a). Frequently, the snow layers were separated by ice lenses - the remains of winter thaws. The total density of the thickness was not great and varied from 0.18 to 0.27 g/cm$^3$.

In the period from the middle of March to the middle of April there also was an increase in the reserves of wetness with heavy snow falls. The daily thaws observed during this time facilitated an increase in the density of the snow cover to 0.22-0.34 g/cm$^3$, and in the wind blown drifts and edges to 0.35-0.40 g/cm$^3$.

The maximum water reserves were observed in areas of snow drifts which should be a factor of both the great thickness of the snow cover (up to 110 cm) and its increase in density (to 0.29 g/cm$^3$). In open fields around Moscow observed snow cover densities ranged from 0.13 to 0.22 g/cm$^3$ during November and from 0.17 to 0.24 g/cm$^3$ during December. In small open sections in wooded areas around Moscow, densities ranged from 0.13 to 0.18 g/cm$^3$ in November and from 0.16 to 0.20 g/cm$^3$ in December. In wooded areas under trees observed densities ranged from 0.13 to 0.18 g/cm$^3$ in November and from 0.15 to 0.20 g/cm$^3$ in December.

4b. Sabo (1962). Study of the formation of snow cover in the forest has been carried out by us during 1956-58 in the Taldom district, Moscow oblast, for the purpose of determining the water balance of swamped forest lands. The studies have been carried out in the same twenty areas during the period of maximal snow supplies. With the help of detailed snow-measuring surveys in different types of forests, with standing timber of varying age and fullness, as well as in field areas, determinations were made of the depth of snow cover, its density and water supplies, referred to hereafter as the "snow supply." A description of the areas and results of the studies with respect to snow depth and snow cover density are presented in the following table [Table A3]:

Table A3. Depth and density of the snow cover in periods of maximal snow supply, 1956-1958.

| | 1956 | | 1957 | | 1958 | |
|---|---|---|---|---|---|---|
| Land | Depth (cm) | Density (g/cm$^3$) | Depth (cm) | Density (g/cm$^3$) | Depth (cm) | Density (g/cm$^3$) |
| Pine Forest | 75.8 | 0.256 | 72.0 | 0.258 | 73.1 | 0.184 |
| | 60.7 | 0.221 | 56.0 | 0.253 | 63.7 | 0.230 |
| | 61.0 | 0.218 | 46.5 | 0.300 | 53.0 | 0.255 |
| Spruce Forest | - | - | - | - | 46.7 | 0.248 |
| | 54.5 | 0.216 | 46.1 | 0.297 | 56.3 | 0.243 |
| | 52.1 | 0.213 | 36.6 | 0.276 | 48.3 | 0.248 |
| | 47.9 | 0.217 | - | - | - | - |
| Birch Forest | 65.8 | 0.235 | - | - | - | - |
| | 62.7 | 0.230 | 53.3 | 0.263 | 61.8 | 0.239 |
| | 57.5 | 0.229 | 48.7 | 0.325 | 56.0 | 0.232 |
| | 62.5 | 0.228 | 55.8 | 0.285 | 59.1 | 0.269 |
| Birch Forest | 63.9 | 0.225 | 54.8 | 0.258 | 60.7 | 0.232 |
| after maint. | 63.8 | 0.234 | 55.0 | 0.275 | 60.3 | 0.257 |
| fellings | 65.2 | 0.240 | 57.9 | 0.265 | 62.9 | 0.243 |
| | 67.2 | 0.241 | 61.2 | 0.253 | 63.5 | 0.249 |
| Glade in forest | 61.0 | 0.240 | 52.9 | 0.304 | 57.5 | 0.267 |
| | 68.0 | 0.281 | 59.5 | 0.310 | 64.2 | 0.248 |
| | - | - | - | - | 45.3 | 0.252 |
| Field | 50.0 | 0.241 | - | - | 45.7 | 0.256 |
| | 44.8 | 0.265 | - | - | 43.6 | 0.264 |

5. AMUR REGION.

Nikol'skaya and Grigor'yev (1960). The average density of the snow cover on the Zeysko-Bureinskaya Plain was 0.29 g/cm$^3$, and the largest was 0.39-0.40 g/cm$^3$. It was observed on sectors with lightly rolling surfaces, among wormwood growths.

At the beginning of March the density of the snow cover approached 0.40 g/cm$^3$ in the Kozloki River Valley. However, the seasonal average density of the snow cover in this area was 0.27 g/cm$^3$. The average density in March in the Burei River Valley was 0.25 g/cm$^3$, while the minimum and maximum were 0.11 and 0.40 g/cm$^3$.

6. EUROPEAN PART OF THE USSR.

6a. Kus'min (1960). Among the more important characteristics determining the water, thermal, radiational, and many other snow cover properties, are the structure and density of the snow. The extreme limits in the variation of snow density are 0.01 and 0.70 g/cm$^3$. The density of dry newly fallen snow which has not lost its initial structure changes from 0.01 to 0.20 g/cm$^3$, small-grain from 0.17 to 0.43 g/cm$^3$, and large grain from 0.32 to 0.49 g/cm$^3$.

The average density of a dry snow cover by the beginning of the spring thaws (at the end of winter) changes over the territory of the European part of the USSR from 0.18 to 0.35 g/cm$^3$ and, on the average, is 0.28 g/cm$^3$. In the north of the European territory of the USSR, the average density of the dry snow cover by the beginning of the thaw changes from 0.22 to 0.28 g/cm$^3$, and in the central area, from 0.24 to 0.32 g/cm$^3$, and in the south from 0.22-0.23 to as high as 0.34-0.36 g/cm$^3$. Snow density in the forest, as a rule, is lower than on the open sectors.

The density of the melting snow cover and the different forms of melting snow were characterized in a laboratory study with the following results. The density of the newly fallen snow, having an initial density of from 0.13 to 0.18 g/cm$^3$, after being dampened by water to its full water capacity and with a free drain of the surplus gravitational water, increases to 0.55-0.60 g/cm$^3$; the density of the granular snow with an initial density of 0.23-0.45 g/cm$^3$ increases after wetting to 0.40-0.50 g/cm$^3$. The density of the naturally melting snow changes at the beginning of thawing from 0.18 to 0.35 g/cm$^3$; at the height of the thaw, from 0.35 to 0.45 g/cm$^3$; and reaches 0.50 g/cm$^3$ by the end of the thaw season. The density of the snow cover in the characteristic dates of [seasonal] thaw varies as follows: at the date of the beginning of snow thawing from 0.24 to 0.41 g/cm$^3$, on the date of the appearance of thaw patches from 0.25 to 0.45 g/cm$^3$, and on the date of snow dwindling on 50% of the area from 0.29 to 0.48 g/cm$^3$.

6b. Vershinina and Volchenko (1974). The water equivalent of snow accumulated over the winter is the main factor determining the magnitude of the spring flood runoff in regions deficient in moisture, since soil moisture varies little from year to year. For this reason, it is particularly important to compute the maximum water equivalents and their variations in these regions.

The southern boundary of the region studied extends along the Smolensk-Vilnius line, the eastern boundary along the Kalinin-Borovichi line, the western boundary along the Daugavpils-Riga-Narva line (with the exception of the Estonian SSR), and the northern boundary along the Narva-Leningrad line.

Regular snow surveys along triangular snow courses in the fields are known to have been initiated in 1936-1938. However they were temporarily discontinued in 1941-1944 and, therefore, continuous snow cover observation records are available only from 1945 to 1949. To compute the long-period mean maximum water equivalent and its variation (coefficients of variation), we used the observation period from 1949 to 1971.

To determine the maximum water equivalent in the forest, the results of snow surveys at 60 points with observation records from 15 to 20 years were used. The results of observations of water equivalent in the forest at each point were then reduced to a single 18-year period....

The average snow depth in the forests of the region under study varied over the observation period from 25-30 cm in the Latvian SSR to 50-60 cm in its eastern part, and in the Valdai Hills in particular. In snowy winters, snow depth may reach 80-100 cm in deciduous and mixed forests. The year-

to-year variations in average snow depth in the forest are fairly large; the coefficient of variation ranges from 0.25 to 0.45.

Snow density in a forest depends largely on the species composition and density of the forest. For this reason, there is no distinct pattern in the distribution of average snow densities in the forest over the region under study, since snow courses in the same area may be located in different types of forests. During the establishment of maximum water equivalent, the average snow density in the forest, just as in the field, varies insignificantly over the territory, from 0.22 to 0.28 g/cm$^3$, and averages 0.25 g/cm$^3$, i.e., 0.03 g/cm$^3$ less than in the field.

6c. Molchanov (1946). The first snow in the Onega Lake District of European USSR is observed during the last ten days of September in the northern section but somewhat later or in the first ten days of October in the southern section. The very latest occurrence of a snow cover in the northern and eastern portions is the first ten days of November, but in the last ten days of November in remaining portions.

A continuous snow cover is established first, on an average, in the middle of October (11 to 20th Oct.) in the northern portion, but about ten days later (21 to 31 Oct.) in the southern portion; only at Klimetskiy Ov and Petrozavodsk (in the central portion) where the climate is influenced considerably by the lake, is the establishment of the cover delayed until the first ten days of November. The disappearance of snow cover in open places occurs (on an average) during the last ten days of April; in forests, it disappears much later or as late as the end of May and in certain cases even up to June.

In exceptionally warm years and winters with little snow, the cover in open places disappears before the 20th of April, and even as early as late March in the southern portion of the basin. Conversely, in winters with heavy snow, the cover lasts until mid-May (11 to 20th) and at some northern stations until the end of May.

During the spring cold waves (return of cold), a post winter snow is possible. For example, in 1930, when snow fell at the beginning of June, the snow remained several days. On an average, the duration of snow cover is 184 to 206 days annually in the northern portion and 178 days at the southernmost station (Voznesen'ye); Klimetskiy Ov, under the lake influence has the shortest duration or a total of 169 days annually.

Generally, the snow depth in late October is one to two centimeters at all stations except at Klimetskiy Ov (lake influence) where such a depth is not recorded until the middle of November (11 to 20th). The depth gradually increases from November through March when maximum depths are recorded everywhere in the basin. The greatest depths occur in the northern and eastern portions of the basin where the mean depth is 54 to 60 cm and the absolute maximum is 92 cm at Morskaya Masel'ga. The absolute maximum depth for the entire basin, however, is in Pudozh (eastern portion) where the depth reached 108 cm. In the western and southern portions, the deepest average depths vary from 30 to 47 cm or about 20 cm less than in the northern portion. Depths in the central portion (lake influence) are relatively smaller.

As for snow density, freshly fallen snow is very [light], but the snow cover density increases as winter progresses. In January, the density is 0.20 to 0.26 g/cm$^3$, but in April (when the thaw sets in) it is 0.38 g/cm$^3$. In winters with great snowfalls, and considerable thawing, the snow cover density may vary within considerable limits. The following snow-cover density data were derived from observations made from 1928 to 1933:

Table A4. Snow cover density data, 1928-1933.

| Station | Location (lat. & long.) | | Elev. (m) |
|---|---|---|---|
| 1. Voznesen'ye | 61°01'N | 35°29'E | 38 |
| 2. Kargopol' | 61°30'N | 38°57'E | 126 |

| Stations | November | | | December | | | January | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 to 10th | 11 to 20th | 21 to 30th | 1 to 10th | 11 to 20th | 21 to 31th | 1 to 10th | 11 to 20th | 21 to 31th |
| 1. Voznesen'ye | | | | | | | | | |
| a. Max | 0.12 | 0.15 | 0.19 | 0.18 | 0.16 | 0.17 | 0.19 | 0.32 | 0.26 |
| b. Avg | — | 0.11 | 0.14 | 0.11 | 0.13 | 0.16 | 0.22 | 0.21 | 0.21 |
| c. Min | — | 0.09 | 0.08 | 0.08 | 0.10 | 0.10 | 0.15 | 0.14 | 0.10 |
| 2. Kargopol' | | | | | | | | | |
| a. Max | — | — | 0.17 | 0.25 | 0.19 | 0.22 | 0.26 | 0.30 | 0.33 |
| b. Avg | — | 0.14 | 0.13 | 0.21 | 0.14 | 0.17 | 0.21 | 0.21 | 0.25 |
| c. Min | — | — | 0.09 | 0.17 | 0.10 | 0.12 | 0.15 | 0.18 | 0.18 |

| Stations | February | | | March | | | April | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 to 10th | 11 to 20th | 21 to 28th | 1 to 10th | 11 to 20th | 21 to 31th | 1 to 10th | 11 to 20th | 21 to 30th |
| 1a. | 0.20 | 0.26 | 0.23 | 0.26 | 0.25 | 0.35 | 0.36 | 0.36 | 0.50 |
| 1b. | 0.17 | 0.21 | 0.20 | 0.21 | 0.21 | 0.26 | 0.30 | 0.32 | 0.38 |
| 1c. | 0.15 | 0.16 | 0.18 | 0.19 | 0.20 | 0.20 | 0.24 | 0.26 | 0.26 |
| 2a. | 0.32 | 0.31 | 0.33 | 0.35 | 0.28 | 0.27 | 0.39 | 0.42 | 0.40 |
| 2b. | 0.24 | 0.25 | 0.25 | 0.26 | 0.23 | 0.24 | 0.29 | 0.36 | 0.38 |
| 2c. | 0.20 | 0.21 | 0.21 | 0.21 | 0.21 | 0.23 | 0.24 | 0.25 | 0.24 |

| Stations | May | | |
|---|---|---|---|
| | 1 to 10th | 11 to 20th | 21 to 31th |
| 1a. | 0.33 | — | — |
| 1b. | — | — | — |
| 1c. | — | — | — |
| 2a. | — | — | — |
| 2b. | 0.31 | — | — |
| 2c. | 0.27 | — | — |

6d. Vershinina and Volchenko (1979). The boundaries of this study area are 56 and 60°N, 47 and 56°E. This area includes the basins of the Vyatka River upstream of Vyatskiye Polyany city (basin area of 124,000 km$^2$), and

the upper courses of the Kama River upstream of Kay village (13,000 km$^2$) and of the Vetluga River upstream of Bystri village (2680 km$^2$).

This territory occupies the eastern part of the East European plain with elevated, dissected interfluves and broad river valleys with gentle terraced slopes. The lowest and most swampy (13-18%) area is the southwestern part of the basin of the Vyatka River, where the lowland crossed by its tributary, the Pizhma River, has elevations of about 100-145 abs. m and the drainage divides rise no more than 170-180 m.

A belt of flattened uplands, the so-called Northern Hills, with elevations somewhat higher than 200 m, extends in the northern part of the region along the drainage divide with the basin of the Northern Dvina River.

The flat Upper Kama upland, deeply dissected by rivers, is located in the upper courses of the Kama, Vyatka, and Cheptsky Rivers. The elevations of the broad and flat drainage divides here do not exceed 330 m.

A stable snow cover usually forms in the study region in the second decade of November and increases most rapidly in early winter.

The water equivalent is usually highest by the end of March in the southern and central regions and by mid April in northern regions.

At the time of establishment of the maximum water equivalent, snow depth in the field averages from 30 to 50 cm (on the right bank of the Lower Vyatka) to 70 to 80 cm in the upper courses of the Vyatka and Kama Rivers. The temporal variations in average snow depth in the field range from 0.26 to 0.30, depending on the water equivalent and local topography.

Snow density in the field varies insignificantly in the period of establishment of the maximum water equivalent from 0.26 to 0.32 g/cm$^3$, and averages 0.28 g/cm$^3$ in most areas. Its temporal variability is also low, averaging 0.10.

The average height of snow cover in forests during the entire period of observation, and within the limits of the experimental territory, changes from 50-60 centimeters in south-eastern regions to 80-90 centimeters in the upper reaches of the Vyatka and Kama Rivers. From year to year changeability of the average figures for the height of snow cover in forests is negligible. The average density of snow cover in forests during the acknowledged periods of maximum snow reserves just as for fields changes only slightly from 0.24 to 0.28 g/cm$^3$, comprising on the average 0.26 g/cm$^3$ which is 0.02 g/cm$^3$ lower than in fields.

The average figures for the maximum water reserves in the snow cover within the limits of the experimental territory and during the observation period change from approximately 120-150 mm in southwestern regions to 230-240 mm in the Verkhnekamsk upland area. During the winters of thick snow cover the snow reserves in forests reach the figure of 250-260 mm. Approximately 10-20% more snow is accumulated in forests than in fields.

## 7. ARCTIC REGIONS.

Bogorodskii (1975). The density of snow cover in the Arctic varies within

great limits depending upon the time of year, the temperature and wind conditions, the thickness of snow cover, and so on. Freshly fallen snow is distinguished by the least density, but depending upon the conditions under which it falls its density may vary by 10 times —from 0.03 g/cm$^3$ (fluffy snow in windless weather) to 0.30 g/cm$^3$ (moist snow).

In its annual trend, the mean snow density [increases] rapidly in the first 2 months and then remains almost constant (0.30-0.35 g/cm$^3$) all winter. At the beginning of the thaw the density rises sharply and attains 0.40-0.45 g/cm$^3$.

The density of snow cover is not uniform in depth. According to the author's observations it increases by two times at a depth of 3 m from 0.22 to 0.45 g/cm$^3$, the growth in density occurring exponentially:

$$\rho = 0.11h^{0.243}$$

where $\rho$ is density, g/cm$^3$, and h is depth, cm.

Temperature has little effect on snow cover compaction: at -2°C the density of freshly fallen snow is 0.10 - 0.11 g/cm$^3$, while at -10°C $\rho$ = 0.07 - 0.08 g/cm$^3$. However, the snow cover compacts rapidly as the wind increases as follows:

| Wind Speed m/s | Snow Density (g/cm$^3$) |
|---|---|
| 0 - 2 | 0.05 - 0.06 |
| 3 - 7 | 0.14 - 0.17 |
| 8 - 15 | 0.18 - 0.22 |
| $\geq$ 16 | 0.23 - 0.33 |

8. THROUGHOUT THE USSR.

8a. Lipovskaya (1968). The principal factors, governing the distribution of the snow cover densities throughout the USSR, are reviewed. In general, the snow cover density was found to increase with the weight of the snow, the wind velocity and the temperature changes. Within the range of 0.27 to 0.36 g/cm$^3$, the density rises by 0.04 g/cm$^3$ for every degree of positive temperature. It also depends on the length of time the snow cover exists. Thus, the density of snow cover triples from 0.05 to 0.15 g/cm$^3$ while its thickness decreases by 8 to 10 times. In temperate zones, the snow cover density is from 0.20 to 0.23 g/cm$^3$ in forested and from 0.25 to 0.27 g/cm$^3$ in unshielded stretches. In the mountains, it varies with the slope, orientation, snow-cover thickness and altitude above sea level. For example, the density increases in the Caucasian Mountains with altitude. The relationship between the snow cover and the topographic relief is shown in Figure A2. The density increases from 0.14-0.16 g/cm$^3$ in the snow-deficient southern regions, to 0.30 g/cm$^3$ on the north shores and to 0.36 g/cm$^3$ on Kamchatka. Fluctuating between 0.20 and 0.22 g/cm$^3$ in the western parts of the European USSR, the density rises to 0.24 g/cm$^3$ on the islands of the Gulf of Riga. It is mostly 0.24 g/cm$^3$ in the interior of the European USSR. In the West Siberian lowlands, the density varies from 0.23 on the south to 0.30 g/cm$^3$ on the shores of the Kara Sea, averaging 0.26 g/cm$^3$ over most of that territory. The narrow strip of [low?] densities, under 0.22 g/cm$^3$ in the south of this territory coincides with the belt of

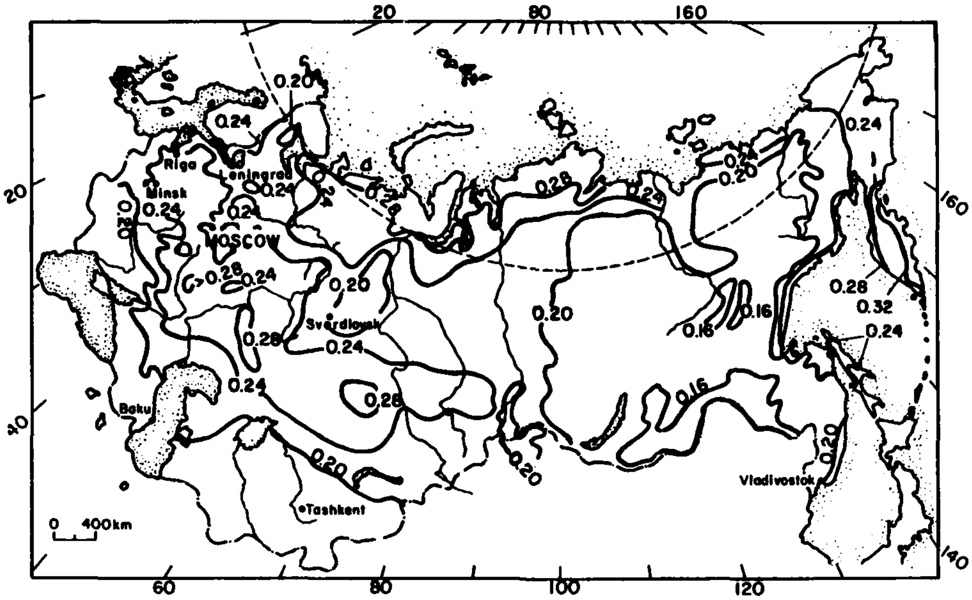


*Figure A2. Average density of snow-cover (greatest 10-year depth for U.S.S.R.) from Lipovskaya (1968).*

winds having velocities of less than 5 m/sec. From there on eastward, the densities increase to 0.20-0.24 g/cm$^3$ on shores of the Sea of Okhotsk.

The greater part of the European territory of the USSR consists of regions having average snow density of 0.24 g/cm$^3$ and more. These regions occupy the area from 47 to 57°N. Lower density values are observed only in northwestern USSR, in the area near the Baltic, in southern Byelorussia, Moldavia, in the southern Ukraine, and along the Volga. On plateaus (Srednerusskaya, Privolzhskaya, and Obshchiy Syrt) density increases to 0.28 g/cm$^3$. Density has a lower value in river valleys because of the considerable protection.

The greater density in the Cisurals and in the northern Urals (more than 0.28 g/cm$^3$) is consistent with the distribution of snow depths and is brought about '; the compaction of snow under its own weight.

Beyond the Urals the lowest values, 0.20 g/cm$^3$, are noted on the Western Siberian plateau, which is explained by the decrease in snow depths and the heavily forested character of the territory (more friable snow). The range of density variations on the Western Siberian Plateau is as follows: from 0.22 g/cm$^3$ in the south to 0.30 g/cm$^3$ along the banks of the Kara Sea. Throughout most of this region density is 0.22 - 0.26 g/cm$^3$. The narrow belt of decreased density (less than 0.22 g/cm$^3$) in the south can be connected with the decrease in snow depths and is consistent with the lower average annual wind velocity, 2.5 - 4 m/s.

All of the northern Kazakhstan, particularily its elevated [illegible], is characterized by an increase in density to 0.28 g/cm$^3$, in spite of the insignificant depths of the snow cover. In this case the compaction of the snow is connected with the high wind velocities - all this territory belongs to the second, and partially to the first, wind regions with wind

velocities of 4-9 m/s. Local relief also has a considerable effect on compaction of snow.

On the lower part of the Central Siberian Plateau density varies from 0.18 g/cm$^3$ to 0.20 g/cm$^3$, and along the shore, to 0.26 g/cm$^3$. Due to the great depths of snow in the mountainous part of the Asian Territory of the USSR, density values must also be high; however, data on these regions are practically nonexistent, and the stations at hand give information on snow density only in river valleys.

Particularly low density values, 0.14-0.16 g/cm$^3$, are observed in the Lena Valley. In Yakutiya and Kolyma stations are also located only in the lower regions and in river valleys. Density distribution in these regions is consistent with depth distribution and mean annual wind velocity; density values here are on the order of 0.20 g/cm$^3$*.

As we progress to the east density increases to 0.30 g/cm$^3$ at Chukotka. Along the coast of the Okhotsk Sea density is 0.20-0.24 g/cm$^3$. The density gradient in the area near the coast is very large.

In a large part of the Transbaykal territory density is insignificant, 0.16-0.18 g/cm$^3$, which is due to the low depths and the low wind velocity. In the mountainous part - the Stanovoy upland and the northern regions of the Yablonovyy upland - we can assume an increase in density of the snow cover. The near-coastal plain region of the Far East record densities of 0.16 to 0.20 g/cm$^3$.

The greatest density for the entire USSR is noted on Kamchatka, particularly in the northeast along the coast, up to 0.36 g/cm$^3$, where the snow is also the deepest.

The results of comparing densities in open and protected areas are presented in the following table [Table A5]:

Table A5. Density of snow cover in protected and open areas, g/cm$^3$.

| Station | Area | | Location | |
|---|---|---|---|---|
| | protected | open | Lat. (N) | Long. (E) |
| Kargopol' | 0.21 | 0.22 | 61°30' | 38°58' |
| Bolotnoye | 0.21 | 0.25 | 55°41' | 84°23' |
| Leushi | 0.19 | 0.22 | 59°39' | 65°47' |
| Tara | 0.26 | 0.28 | 56°54' | 74°23' |
| Cheremkhovo | 0.18 | 0.20 | 53°09' | 103°05' |
| Sretensk | 0.14 | 0.16 | 52°15' | 117°43' |
| Uryupinsk | 0.28 | 0.27 | 50°47' | 42°00' |
| Kolomak | 0.26 | 0.26 | 49°50' | 35°40' |

*During a visit to the upper reaches of the Vstrecha Creek Basin at the Kolyma Water Balance Station, Slaughter and Bilello (1977 - see list of cited references in text) obtained the following information. Snow depth measurement transects are made at 10-m intervals, along six marked lines running from ridgeline to ridgeline; snow water equivalent is measured at 100-m intervals. The frequency of snowpack measurement, depending on site, is every 10 days from date of first snow, monthly or annually at maximum accumulation. Spring snowmelt at the station begins in mid-April; snowpack density prior to spring melt ranges from 0.14 to 0.26 g/cm$^3$.

8b. Kopanev (1978). Snow cover density is one of the important characteristics in scientific and practical studies of snow cover. Many factors determine the spacio-temporal fluctuations of snow density. Constant physical processes, the intensity of which depends on the nature of the precipitation and the thermo-cycle between the snow cover and the layer of atmosphere near the ground, begin to operate as soon as the snow layer is formed. Liquid precipitation usually solidifies snow cover, whereas thaws, followed by the melting of the snow, have a loosening effect; at low temperatures, however, a thaw may cause such a high density snow cover that a snow-crust will be formed.

The density of fresh snow depends on the air temperature during the falling of the snow (at relatively high temperatures there is a considerable increase in snow density), as well as on the size of the snow-flakes (small snow-flakes on windy days contribute to the formation of a relatively dense snow-cover). Snow density increases with the increase in the wind velocity even if all other conditions remain the same.

Snow density in areas exposed to wind is particularly affected; the wind is also the determining factor in regions where liquid precipitation or thaws occur rarely. Snow density in places well sheltered from the wind is not great since there it depends solely on the weight of the snow cover itself. Relatively dense snow covers are found in places exposed to the wind.

Recently published systematized data on the snow density of several areas of the Soviet Union show the average snow density, on days when the snow cover was the highest in Western Siberia, fluctuates from 0.19 to 0.22 g/cm$^3$ in the forest zone and from 0.22 to 0.31 g/cm$^3$ in the forested-steppe and steppe regions.

The work of V.I. Lipovskaya is of great interest since she was the first to make a map of the average snow density for the entire territory of the Soviet Union. The map reflects changes in the snow density in areas of maximum snow cover. The result of processing the snow measurements obtained from 800 posts and stations confirm the data about density distribution in different regions of the country. Regions of unstable snow cover (0.13-0.16 g/cm$^3$) are characterized by minimal snow cover, which is the highest in the northern regions of Kazakhstan (0.24-0.28 g/cm$^3$).

Average snow cover densities collected on the basis of a survey (1935-1965) conducted during the last ten days of each month show that the density increases, from month to month, simultaneously in all areas of the country. Over the largest part of the territory of the Soviet Union the greatest snow density was observed in forest clearings in March and in regions with prolonged cold periods in April.

During cold periods, differences in density between field and forest areas gradually become negligible and are least when snow precipitation reaches its peak (which usually takes place before the spring thawing).

There is no distinct zonal character in the density distribution in the months of March and April. In the European part of the USSR (ETS), for example, only a slight tendency toward growth is observed in a north-south direction. Meridional changes however, are more evident. In the central

European part of the USSR the density of snow in March and April in open spaces comprises 0.28-0.40 g/cm$^3$, while in Yakutia the figures are 0.19-0.22 g/cm$^3$. Absolute figures for forested areas of the mentioned regions show little difference.

Snow density in field areas is greater than under forest canopies and forest clearings. Density figures for clearings in forests and wooded areas are not the same in different regions of the country, i.e., the density in forest clearings may be equal to or less than the density in wooded areas. In the months of March and April the density in forest clearings in some areas does not differ significantly from the density in wooded areas. This is true of the Southern and Northern areas of ETS and of Eastern Siberia.

It may seem that the snow cover under the protection of trees in a forest is less affected by wind, solar radiation, etc., than that in open clearings. Fluctuation in the density distribution in forest clearings and in wooded areas is accounted for by inadequate methods of measuring snow density. Besides, changes in the height of the snow cover in forest clearings may occur as a result of thaws. If snow falls after a thaw in areas protected by trees where the old snow has been almost entirely preserved, the density may be somewhat higher than that in most of the forest clearings. The differences in the density between field and forest areas (for the months of March and April) are not high - particularly in the regions of Eastern Siberia.

8c. Zavarina (1976). The greatest snow cover density in the USSR is naturally seen in those regions where the snow cover is deepest. In regions with little snow, the density is lower than that in regions with much snow by a factor of 2-2.5.

Throughout the country, the average density values range — under the influence of different factors — from 0.14 (in the Trans-Baykal) to 0.36 g/cm$^3$ (on the Kamchatka Peninsula); with a noticeable increase in snow cover density as the latitude increases. Snow density should increase as the air temperature rises. Consequently, its high value in the northern regions in comparison with the southern ones is explained by the action of other factors: first, the extended duration of its existence; second, the effect of a stronger wind. The joint effect of these factors overshadows the effect of air temperature.

Because snow cover depth increases as the altitude of an area above sea level does, so does the density of the snow. In winters with much snow, the change in the average density per 100 m of altitude reaches 0.02 g/cm$^3$.

The degree of exposure of an area also affects snow cover density. As a rule, the density of the snow in exposed sections of forest-steppe and steppe regions is somewhat higher than in protected sections; this is apparently related to wind action. The difference between the densities reaches 5-10 percent.

In the southern region of the USSR, on the other hand, snow density in exposed sections is even somewhat less than in shielded ones. This can be

explained by the fact that here the difference in the duration of the snow cover's existence has a greater effect.

The average values characterize snow cover density quite well, since its variability from year to year is not great. For example, the coefficient of variability, as calculated for the territory encompassing the upper reaches of the Lena River, equals 0.09, while in the mountainous region of Kirgiziya it is even greater, but still does not exceed 0.18.

## 9. SELECTED AREAS IN THE USSR.

9a. Rikhter (1954). In the Arctic and the southeastern European portions of the USSR where snowfall is usually accompanied by strong winds or gales, the density of the snow cover tends to be higher than in the south and west. In eastern Siberia, with its lasting frosts and negligible wind velocities, the density of the snow cover remains very low all winter long.

The density of the snow becomes greater steadily all winter long, with the result that in spring the density of the snow cover is at its greatest in all its layers. The density of the snow cover as a whole rises an average of 10 to 12 percent per month.

The density of the snow cover increases most rapidly during warm spells and thaws, when it may change noticeably in 24 hours. The process whereby density increases proceeds without interruption during both warm spells and frosts, but it operates more slowly during frosts than warm spells. Contrary to the case of newly fallen snow, the density of the snow cover increases without interruption from fall to spring.

Snow cover may be divided into the following five groups by density: 1) very loose, with a density of 0.01 to 0.1; 2) loose, with a density of 0.1 to 0.25; 3) medium, 0.25 to 0.35; 4) dense, 0.35 to 0.45; 5) very dense, over 0.45.

When snow reaches a density of 0.32 to 0.35, it will sustain a pedestrian without skis. At 0.35 to 0.38, the foot hardly leaves a mark. At over 0.4, the snow will sustain a horse, and the human foot leaves no mark whatever.

The wheels of a horse-drawn wagon no longer break through when the density is over 0.3 or 0.35, but heavy trucks require a density of not less than 0.5.

Systematic records of snow density have been conducted by only a very small number of weather stations, and even these observations have, for the most part, not been processed and published to date.

The density of snow cover is exceedingly unstable both in time and space and is subject to extreme fluctuation (from 0.01 to 0.7) as a result of climatic conditions. These circumstances make it impossible to compile any more or less complete description of the geographical distribution of average snow cover density throughout the USSR., or of changes therein in time. We can provide only the following partial data on average density, month to month.

November. At the beginning of the period of snow accumulation when the snow has as yet not been packed down and redeposited by the wind, density does not vary greatly and is approximately 0.15. It is somewhat higher only in the far north (0.20-0.25), where it is packed down by strong winds and storms immediately after it has fallen.

December. The average density over most of the USSR now ranges between 0.16 and 0.20. It is somewhat above that in highland areas, and also in southeast European USSR and in the far north. In the central areas of eastern Siberia, it is insignificant and usually does not exceed 0.15.

January. The average snow density in European USSR is about 0.20, rising toward the north and the southeast to 0.25-0.26. In the Arctic proper, it reaches and exceeds 0.3. Minimum density (0.15, approximately) is recorded in eastern Siberia, where snowstorms and thaws are equally almost entirely lacking in January.

February. The average density of snow in European USSR is about 0.23-0.24. Higher average densities are recorded in the north where storms, tending to pack it down, prevail in the southeast (0.27-0.28), in the central Russian Upland (0.26-0.27) and in the west (0.25-0.26) where this is due to repeated thaws. The figure is at its highest in the Arctic, where it reaches 0.30-0.32. It is lowest in central and eastern Siberia, at 0.15.

March. The average density of the snow over most of the territory of European USSR is 0.28. In the southwest and west, where rapid thawing has begun, the average density increases to 0.30. Approximately the same order of magnitude is attained in the Arctic, at 0.30-0.33. In eastern Siberia it is now about 0.20.

April. In most districts of the USSR during this month, rapid packing down and thawing of the snow takes place, with its density climbing to 0.35. The same average holds in the Arctic as well. The lowest average density at this time is about 0.22, recorded in eastern Siberia.

May and June. Snow on the ground remains only in the far north and the Arctic, where it attains the highest of average densities (0.4-0.6 $g/cm^3$).

9b. Trifonova (1962). The variability and precision in determining the density of a snow cover under various physical-geographic conditions was evaluated. For this purpose [the following snow cover density values] were obtained from snow surveys made in different regions of the USSR:

| Snow survey region | Elevation m | Density $g/cm^3$ |
|---|---|---|
| Kzylsu River | 125 | 0.30 |
| Karakol River | 91 | 0.23 |
| Koluton Station | 1050 | 0.14 |
| Valday Station | 636 | 0.23 |
| Oksochi Station | 350 | 0.19 |
| Koltushi Settlement | 92 | 0.32 |

1. The following expedition snow surveys of the State Hydrological Institute were conducted in Kazakhstan (Tselinogradskaya Oblast) at the end of March 1956:

a) the snow survey route over a triangle with a total length of around 30 km within the limits of the basin of the Kzylsu River. The measurements of snow cover density were measured every 250 m (a total of 120 measurements).

b) snow surveys along two routes 10 and 13 km long along the Karakol River Valley (the first route ran along the right bank of the river, and the second along the left). The measurements of snow cover density were made every 250 m (a total of 900 measurements).

c) the snow surveys over 13 parallel routes crossing the channel of the Karakol River. The routes were located a distance of 100 m apart.

d) the snow surveys along 10 routes located in the region of Koluton Station. The total length of the routes was 10 km. The measurements of the snow density were made every 50 m. During the winter of 1954-1955, 5 snow surveys were made.

2. The data of the snow surveys by the Valday NIGL (nauchno-issledovatel'skaya geofizicheskaya laboratoriya) were made in the basin of the Polomet' River in February 1953. A total of more than 600 measurements were made for snow cover density.

3. The snow-measuring survey routes near Oksochi Station (the Northwestern UGNS [upravleniye gidrometeorologicheskoy sluzhby; administration of the hydrometeorological service]), in the basins of the tribuaries of the Gridenki River (the Smolechanka and Oksochi Rivers). The snow surveys were made over two routes with a total length of 5, 100 m during two winters (1955-1956, 1956-1957). Snow cover density was measured every 100 m.

4. The snow survey route in the region of Koltushi Settlement of Leningradskaya Oblast consisting of two parallel routes aorund 500 m long each. The measurements of snow cover density on the routes were made every 10 m.

9c. Dmitrieva (1950). Systematic observations of snow density were begun in Russia in 1903-04. However, sufficient data on snow density were not collected even for such regions of European USSR as the Ukraine and the Northeast at the time the quantitative surveys of water resources were made during 1931-35. Data on density are scarcest for Siberia, especially the mountain regions....

The density of freshly fallen snow depends on snowflake size. Snow falls composed of large snowflakes reached densities of 0.056, medium flakes 0.091, and small ones 0.135 g/cm$^3$. Fresh snow then rapidly settles to a density of 0.14-0.16 g/cm$^3$.

The pressure of fresh snow on underlying layers is the first cause of increase in snow density. However, the snow crust under natural conditions

usually resists the action of gravity and contributes to a more regular distribution of load. The sublimation processes diminish the density of lower snow layers. In the forests of the temperate zone, where wind influence is low, the mean snow density near the end of winter does not exceed 0.20-0.23 g/cm$^3$. Thus the mean snow settling during 3-4 winter months is negligible if the density of fresh snow is 0.14-0.16 g/cm$^3$.

The generally well-known compaction effect of winter and spring thaw weather is also important. Some meltwater remains in the snow as a result of snow melting and causes an increase in the density of the snow. Obviously, considerable snow-cover compression will occur during alternating frost and thaw weather, as well as in areas where runoff of meltwater is hampered (in hollows and on slight slopes).

Facet fusion of snowflakes, subsequent settling, and compression of snow cover accompany the snow-melting process. Observations showed the dependency of snow density of the sum of positive mean diurnal air temperatures accumulated to the data of observations. These observations indicated than an increase in density of 0.004 over a density range of 0.27-0.36 g/cm$^3$ corresponds to one degree of positive air temperature.

9d. Formozov (1939). In the northern portion of the European part of the USSR the snow cover lasts more than 200 days per year, and in many places in Siberia for 250 days and more. The average maximum snow depth in many places in Northern Siberia is 100 to 140 cm. In Teriberka (Murmansk coast) the number of days per year with snow-cover is 211; in Pustozersk 223 days, with an average maximum thickness of 72 cm. In New Port (southern part of the tundra on the Yamal Peninsula) the snow cover remains for about 9 months from the first 10 days of October until the end of June. Average depth in April and May is 65 cm. On Dickson Island snow remains for an average of 266 days and maximum depth is about 30 cm. Maximum snow cover is especially deep in the tundra of the western part of Siberia ranging from 100 to 140 cm. On the north coast, near the mouth of the Yana River, the thickness of the cover reaches 20 cm. At Anadyr Krai and on the Chukchi Peninsula it reaches 60 to 70 cm, and at Kamchatka as much as 90 to 100 cm. Extreme roughness of the weather which is peculiar to the winter season in the tundra, gives an unequal distribution of the snow cover and a high snow density. These conditions are linked with the steadiness and strength of the wind.

The density of snow on Novaya Zemlya (Matochkin Shore) in January is equal to 0.28 to 0.35 g/cm$^3$, in May it reaches 0.39 and June 0.40 to 0.50 g/cm$^3$. The west side of the Island, along with winds of less strength, the density in March was not greater than 0.27 to 0.30 g/cm$^3$. At Marre-Sale in April 1921 the density was 0.36 and for greater Lyakhov Island (May 1931 and 1934) it ranged from 0.34 to 0.38 g/cm$^3$. On Dickson Island toward the spring it was 0.38 g/cm$^3$.

The depth of the snow cover in the broad leaf forest of European USSR increases from 0 to 5 cm in the southwest (Onesti region) to 40-50 cm toward the north and east central region (i.e. area along the Volga River).

Snow depth at Karelia averages 40 cm and increased to 80-90 cm eastward near the head waters of the Pechora River and to 95 cm at Shogor. In

western Siberia along the lower parts of the Ob' and Toz Rivers there is an abundance of cyclonic activity causing large accumulations of snow. The average maximum snow depth here reaches 100-140 cm. Maximum snow depth observed at Surgut is 80 cm, at Turukhansk 109 cm and central Siberia 50 to 70 cm.

Irkutsk Oblast, Yakutia, and Transbaikal is a region of less snow; toward the month of March snow cover reaches an averge of 37 cm at Yakutsk, 27 cm at Verkhoyansk, and at Irkutsk (in February) only 22 cm. Snow depth along the Pacific Coast, for example at Okhotsk, averages 50-60 cm at Kamchatka 100 cm: 5 cm at Blagoveshchensk, 10 cm at Vladivostok but 50 to 70 cm along the lower Amur River.

Toward the end of the winter 1892-93, the density of snow in Lesnoye in the areas between trees was 0.11 and in the glade it was 0.13 $g/cm^3$. During most of the winter the density did not exceed 0.18 and only toward April did it reach 0.32 $g/cm^3$.

The snow cover in the great plains and deserts of Russia is compacted by high winds and blown into the hollows and gullies leaving slopes, and hills bare. The density in these areas is higher than in the forest regions, averaging around 0.29 $g/cm^3$.

9e. Kuz'min (1960). The particular conditions and distribution of the snow cover and its properties were studies for the Siberian forest-steppe region. In the case of strong winds (10-15 m/s), the snow is completely removed from exposed area. The snow is pulverized by the winds blowing from Kazakhstan dry steppes, becoming amorphous and mixed with a considerable amount of dust. Pure snow, having a normal structure, is found only in sections within forests. Exceedingly uneven deposition of the snow is observed.

Charts of the depth, the density, and the water equivalent of the snow cover were plotted from the data of snow surveys by triangulation on open country, in 1935-1953, for the southeasten part of the West Siberian Lowland (the Tomsk and Novsibirsk Regions, the level part of the Altai region, and the extreme north of the Kemerov Region). The many-year average of the maximum depth of the snow cover is from 22 to 50 cm in steppe and forest-steppe zones, and from 50 to 70 cm in the forest zone. Accordingly, the many-year averages of the water equivalent of the snow cover in the ten-day period with maximum snow depth are from 70 to 110 mm in steppe and forest-steepe zones, and from 100 to 140 mm in the forest zone. The norms of snow depth and water equivalent of the snow cover may be almost double those given above in snowy years, and half to a third less in years with sparse snow. The mean density of the snow cover in the period when maximum depth is attained varies in the forest zone from 0.19 to 0.22, and in steppes and forest-steppes from 0.22 to 0.31 $g/cm^3$.

The mean density of the snow cover is 0.27-0.30 $g/cm^3$ in North Kazakhstan, and 0.30-0.35 $g/cm^3$ in central and West Kazakhstan. The snow-measuring stations from which readings were used between 31 m and 675 m above sea level. The water equivalent of the snow cover increased with the altitude of the station by 15-17 mm per 100 m height on the average.

The largest water equivalents of the snow cover at the beginning of the thaw are observed in the higher areas of the investigated region of Kazakhstan, where they reached 100-120 mm; on plains they decrease to 50-60 mm, and in the southwest they may be as low as 30 mm.

The average maximum depth, and daily values of the depth, density and water equivalent of the snow cover for each station from data of snow surveys by triangulation at 52 stations in Lower Volga region were obtained over periods of 6 to 10 years (1926-27/1936-37). The many-year averages of the maximum depth of the snow cover in this district decrease in a north-south direction to 10 cm. The many-year average density of the snow varies over this area, at the end of February, from 0.23 to 0.32; during the thaw it increases to 0.40. The maximum winter water equivalents of the snow cover are observed in the northern part of the area, where they attain average values of 80-85 mm, with a maximum at Karabulak (112 mm), decreasing southward down to 25-50 mm.

While the forests of Byelorussia are characterized by a relatively even deposition of snow and by its density (0.19-0.22 in forests and 0.25 in fields), the Soviet Arctic is distinguished by an extremely irregular distribution of the snow cover and a relatively higher density. Thus, the snow survey carried out in April 1934 on Dickson Island showed that the maximum depth of the snow cover (1982 cm) was 5.2 times the average value (35 cm), while the minimum depth (4 cm) was only 11% of the average value.

The depth of the snow in the Arctic is generally quite small, because of the small amount of precipitation. At the end of the winter the average depth varies betwen 10 to 80 cm, according to the data of surveys at 15 stations. In different years this value may vary considerably, and be much greater or much smaller (by a factor of 6 or more). This is caused by transport processes due to the strong winds, and not because of changes in the amount of the precipitation, this being fairly constant. The snow density in the Arctic is about 0.25 mm at the beginning of winter and increased up to 0.36 mm or even more, at the beginning of thaw.

The onset of the season with a stable snow cover in the European Territory of the USSR (ETS) is abrupt only in specific years. Usually, it is preceded by an intermediate period, from original formation of the snow cover until it definite consolidation. Generally two "temporary covers" may form, during this period, but in certain years up to 5-6 may occur.

The many-year average of the duration of such a "pre-winter" season is 20-30 days. The period of a stable snow cover lasts, on the average, from 80 days in the southwest of the ETS, to 175 days in the northeast. The period of the thaw (in non-homogeneous areas) lasts from 8-9 days in the south to 15-19 days in the north of the ETS. After the first disappearance of the snow in spring new formation of a continuous snow cover (post-winter) is frequently observed.

The total duration of the period from the disappearance of the permanent winter snow cover to the last day on which a snow cover can be observed, is, on the average, from 3-8 to 16-22 days.

The many-year average of the water equivalent of the snow cover in the ETS, at the end of the season with a stable snow cover (in the ten-day

period with the maximum depth for the winter) increases from the southwest to the northeast. It reaches 160-220 mm on the western slopes of the Urals, and on the adjacent areas to the west.

## 10. TERSKOL PEAK AND ASAU RIVER VALLEY.

Kuvaeva, Sulakvelidze, Chitadze, Chotorlishvili and El'mesov (1967). At the edges of layers of differing snow density, an acute modification in the character of the snow cover takes place; crystals with distinct traits of metamorphism are formed in an above-lying layer. Their appearance is evidently connected with the movement of water vapor. To confirm this, an observation was conducted on Terskol Peak (43°18'N, 42°32'E) from March 13 to May 5, 1959. During that period several layers were distinctly evident in the snow mass: a layer of deep hoar-frost was at the bottom; a layer of fine-grained snow above it (with the density of 0.33 $g/cm^3$), a layer of packed snow (0.4 $g/cm^3$), a snowstorm type fine-grained snow still higher, and a layer of deep hoarfrost of 0.27-$g/cm^3$ density above it.

During the entire experiment, lasting 36 days, the amount of vapor transferred from the layer above the packed snow was twice as much as the amount of water vapor passing from the layer below the packed snow. This means, that on sunny days and in layers of packed snow close to the surface (up to 30 cm) intensive evaporation takes place above it due to solar radiation and conditions are created for the formation of deep hoarfrost.

Experiments were conducted to see how the movement of water vapor affects the density of the snow cover. Evaporation was found to occur in all layers at the bottom of the valley and the volume of evaporation increases toward the snow surface. Within a month, the snow density in that area decreased by 0.003 -0.004 $g/cm^3$. Evaporation constantly occurred in the lower layer of the northern slope whereas the upper layer remained unchanged for a long time. In 25 days the snow density in the lower layer decreased by 0.005 $g/cm^3$, and in the upper by less than 0.001 $g/cm^3$. Less evaporation from the surface layer of the northern slope can be accounted for by the decrease in temperature index in the direction from ground to snow surface. The southern slope presented quite a different picture. For the majority of the observation period the snow mass increased (by 0.001 $g/cm^3$ in 20 days). This was caused by an increase in temperature in the upper layer from solar radiation and on the ground an increase in temperature owing to radiation absorption (the snow [depth] did not exceed 30 cm). As a result, temperature conditions were created inside the snow mass such that water vapor was forced to move from the ground into the snow mass and from the upper layer of snow to the lower.

Evaporation from the lower, 10-centimeter layer in the Azau river valley, on Terskol Peak and the Ice base was measured throughout 1960/61 winter. Average evaporation was equal to that registered in 1958-59 winter. On the whole, during that winter, snow density in the lower 10-cm layer at the altitude of 2200 m above sea level decreased by 1.5-2%, and at an altitude of 3100 m above sea level - by 2%, and at 3700 m altitude by 2-2.5%. The evaporation from the lower layer of the snow mass at different altitude zones changed insignificantly, mainly owing to the fact that the water vapor movement through the lower layers slowed down because of a large accumulation of snow that can be accounted for by longer winter periods at higher altitudes.

The results of the experiment show that there is practically no decrease in snow density owing to evaporation processes in the Elbrus area (up to an altitude of 3700 m above sea level). The snow density decrease caused by 3% evaporation during the entire winter period is more than compensated for by the sinking of the snow cover as the result of which the cohesion between particles in the lower layers remains the same.

## 11. IRKUTSK.

Rozental (1904). Snow density measurements of freshly fallen snow, and at various depths within the snow cover were made at Irkutsk, USSR, during the winters of 1899, 1902 and 1903. The results of the study showed that the density of fresh snow depended upon the structure and size of the original snowflakes. The density of new snow consisting of large flakes ranged from 0.044 to 0.066 g/cm$^3$; for medium sized flakes from 0.078 to 0.118 g/cm$^3$; and for small flakes from 0.130 to 0.141 g/cm$^3$. The average density of fresh snow for 13 separate storms at Irkutsk was 0.093 g/cm$^3$.

The snow cover densities for the top layer of snow (surface to 5-cm depth) following each new snowfall increased from values of 0.059 to 0.133 g/cm$^3$ on the first day of accumulation to between 0.175 and 0.263 g/cm$^3$ after periods of 5 to 14 days of time. According to consecutive measurements made after five new snowfalls the density increase per day in the top layer of snow cover is approximately 0.01 g/cm$^3$. Deviations from the norm were associated with surface wind speeds of 10 m/sec and/or melting.

Average snow cover profile densities for the three winters of observation at Irkutsk were given as follows: for the layer of surface to 5-cm depth 0.141 g/cm$^3$; for 5 to 10-cm depth 0.214 g/cm$^3$ and for below 10-cm 0.226 g/cm$^3$. The greatest observed density (0.385 g/cm$^3$ occurred twice in 1899 - on 24 January and 18 March. In the first case the sample was taken from a snow pile at a depth of 15 to 27 cm, and in the second case it was taken from the surface during melting. Incidentally, on 18 March 1899 a second snow surface measurement taken in the same area except that the snow cover is almost entirely shaded throughout the day, the density was much lower (0.263 g/cm$^3$).

## 12. USSR TAIGA.

Kolomyts (1964). In analyzing the data supplied by research studies of the snow cover in the mountainous taiga of the Zabaykal regions over a period comprising the last few winters, and adding to this data an examination of the few published studies on the snow cover in other regions of Siberia and the Far East, we are made aware of the sharp differences between the snow cover in Siberia and the North Eastern regions and that in the European and Maritime. Differences have been revealed not only in the depth of the snow and the length of time it covers the ground, but to even a greater extent in its stratification and density (general as well as strata density), and accordingly in the nature of the evolution of the snow mass. This leads to the thought that the winter conditions of one or another geosystem can be determined by the character of the development (the stratification) of the snow cover. By the latter we mean that combination of elements, the stratification, depth and density of the snow, which reflect the entire complex of winter conditions of the given regional or cartographical unit.

Of all parametric data, that which is of decisive importance is the stratification of the snow, connected as it is with the most complicated and many-sided aspects of the winter regime of the given geosystem.

The most significant provincial peculiarities of winter in various regions of the USSR taiga conform to types and subtypes of development. The criteria for determining these types are: 1) seasonal changes in the snow mass determining the character and speed of its melting, and 2) the tendency and intensity of the metamorphism of the snow mass, reflecting the exchange of heat between various components of the landscape in winter. For USSR territories characterized by plains and low mountains, three basic types of the snow mass have been determined; we propose calling them: 1) syngenetic, 2) epigenetic, and 3) transitional types.

1. The syngenetic type is characteristic of large regions with a moderate continental winter, where the accumulation of snow continues throughout the entire winter season (as in the taiga of the European part of the USSR, the Maritime Region and the eastern coast of Kamchatka). The snow cover offers summarized information about the winter regime, simultaneously (synchronous) with its own accumulation, and therefore may be considered a peculiar kind of chronicle of the winter season. The order of the basic stages of winter is recorded by marked changes in the snow mass: in its horizon, stratification, and simultaneous growth. In this lies the essence of its syngenesis (analogous with permafrost).

The snow cover is deep: the maximal mean depth is from 50-70 cm and more. With moderate frosts this creates a relatively low temperature gradient within the snow mass, an average of 0.1-0.3°C/cm and accordingly, a low degree of secondary super-crystallization of the mass. The dominant process in these conditions is a breaking down of the structure, i.e., firm snow formation: the transformation of initial idiomorphic crystals into round seed of various sizes. This process is attended by the settling of the snow and an increase in density; it takes place most energetically at times of thaw. The result is that by the end of winter, the density of the snow near the southern boundaries of the European taiga reaches 0.27-0.35 $g/cm^3$ and in the northwest 0.40-0.45 $g/cm^3$. In accumulations of old snow we find the formation of secondary crystals - deep hoarfrost (snow sand), lying off to one side of the general development of the snow.

The syngenetic type of layer may be divided into two subtypes: depending on the degree of the development of texture and structural characteristics of the snow cover, i.e., the correlation of the rate of snow accumulation on one hand and the intensity of its evolution on the other. The layers in the first subtype are distinguished mainly by their texture characteristics. This subtype is most characteristic of the syngenetic type and is particularly often encountered in the taiga area of the Primorie. It is formed in the process of periodic (spasmodic) snow accumulation as a result of frequent alternation of snow falling and snow storms, frosts and melting periods. The second subtype is not characterized by such clear distinction of layers which are recognized mainly by their structural peculiarities. This is an initial shift to the second type. It may be regarded as the beginning of the modification toward the second type. This subtype is spread in the north of the ETS and in the Priuralye as well as along the Pacific shoreline of Kamchatka.

2. The epigenetic type is widely spread in the taiga areas with severe and comparatively snow-free winters and extremely uneven seasonal solid precipitation in Middle Siberia, Jakuria, central mountainous areas and depressions of the Altai, the Sayan and Zabaykalye regions as well as on the left-bank of the middle reaches of the Amur. In these regions the main bulk of snow falls during the first 1.5-2 months of winter (before a stable anticyclone period of air mass sets in); that is why the peculiarities of the winter season develop in an already formed snow layer of one age-period (epigenesis). The height of snow does [not] exceed 20-30 cm; this factor with the continued domination of low temperatures contributes to high temperature [gradient] in the snow cover (of up to 1.5-2°C/cm).

Slight transportation of snow during snow storms and almost no melting periods help form the initial homogeneity of the snow. The formation of the snow cover is closely connected with winter mass- and thermo-exchange between ground layers and the above-ground layer of air as a result of which these processes predominate in the vertical direction. Extremely high activity of the latter accelerates structural metamorphosis of snow under the action of sublimation. The following accompanying phenomena were registered: intensive growth of crystals, the appearance of columnar-type formations and of secondary (epigenetic) differentiation of the snow cover, connected, evidently, with sharp, periodic (daily) temperature fluctuations and deep penetration of direct solar radiation into snow cover. By the end of winter the entire body of snow has modified its crystal structure completely and is then almost entirely composed of deep hoar crystals reaching in diameter from 3 to 5 mm. There are no sharp demarcations between layers; the differences are of a structural nature and can be traced only by the size of the crystals, the cohesive force (solidity) volume weight and other physical and mechanical characteristics of snow. Judging by isolated data, snow cover of the Northeastern taiga regions of the Soviet Union bears a similar structural resemblance.

The distribution of snow in the forest-steppe regions of Zabaykalye and on forestless areas of Central Jakutia as well as in the depressions of Verkhoyanye, Pribaykalye and Stanovoye upland has its own peculiarities. Energetic transportation of snow in the beginning of winter stimulates the initial differentiation of the snow cover which continues to take place. The mirroring effect of the upper layers affected by snow storms upon the migration of water vapor stimulates constructive metamorphism of the below lying layers and this makes it possible to classify this modification process of epigenetic type of deposition as a subtype.

The epigenetic type as compared with other types has the lowest snow density. In Zabaykalye and Priamurye the density by the end of winter comprised from 0.12 to 0.15 and to 0.18-0.20 $g/cm^3$ and in the Northeast of the Soviet Union - from 0.15-0.17 to 0.20 $g/cm^3$.

3. The transitional type is predominant in the taiga region of the West Siberian lowland, along the Okhotsk shoreline and partly on the left-bank of the Amur lowlands. The height of the snow cover is quite large here - 40-70 cm. The snow density ranges from 0.19-0.20 to 0.23-0.25 $g/cm^3$. In structure and composition of snow this type is evidently closer to the second subtype of the syngenetic type, but differs from it by a lesser initial differentiation of the mass and by clearer traces of the evolution of constructive metamorphism.

Alpine regions of Siberia and the Far East are distinguished from the plain regions of taiga by differentiation in the characteristics of snow cover not only in the horizontal layers but in vertical as well. The snow cover in the foothill area as well as in the center of mountains develops on the whole in the same way as in surrounding taiga areas of the plains and depressions. However, "taiga uplands" including the upper parts of the mountain taiga and bare spaces is chara terized by very specific snow distribution affected by transportation of snow during snow-storms as well as by the factor of snow accumulation that sets in during pre-spring and spring months. Two different layers develop in the stratigraphic column of snow; the lower layer is formed by intensive snow falls at the beginning of winter. By winter it reflects (in its structural peculiarities) the results of metamorphism processes in the snow cover taking place during the mid-winter months when snow falling sharply decreases (epigenesis). The upper layer of snow cover determines the spring and summer seasons (syngenesis). In this way the snow cover has two segments and may be classified as alpine polygenetic (episyngenetic) type with the predominance of constructive metamorphism of crystals.

## 13. USSR SNOW SURVEYS.

Vershinina (1969). This paper examines the accuracy in determining snow water equivalent at a point, over a course and over an area, from data of special snow surveys carried out by the State Hydrological Institute in different physicogeographical regions of the Soviet Union. The data used were collected by continuous, landscape-course and course snow surveys during 1963-1968.

An estimate of the instrumental errors in determining snow water equivalent is shown in the following table [Table A6]:

Table A6. Instrumental errors in determining snow water equivalent.

| Snow density, $g/cm^3$ | Snow depth, cm | Snow-density measurement error $g/cm^3$ | Water equivalent of snow, mm | Error in determining water equivalent of snow, % |
|---|---|---|---|---|
| 0.10 | 5 | 0.040 | 5 | 40 |
| | 10 | 0.020 | 10 | 20 |
| | 15 | 0.013 | 15 | 13 |
| | 20 | 0.010 | 20 | 10 |
| | 30 | 0.007 | 30 | 7 |
| | 40 | 0.005 | 40 | 5 |
| | 50 | 0.004 | 50 | 4 |
| 0.20 | 5 | 0.060 | 10 | 30 |
| | 10 | 0.030 | 20 | 15 |
| | 15 | 0.020 | 30 | 10 |
| | 20 | 0.015 | 40 | 8 |
| | 30 | 0.010 | 60 | 5 |
| | 40 | 0.007 | 80 | 4 |
| | 50 | 0.006 | 100 | 3 |

Table A6 (cont'd). Instrumental errors in determining snow water equivalent.

| Snow density, g/cm$^3$ | Snow depth, cm | Snow-density measurement error g/cm$^3$ | Water equivalent of snow, mm | Error in determining water equivalent of snow, % |
|---|---|---|---|---|
| 0.30 | 5 | 0.080 | 15 | 27 |
| | 10 | 0.040 | 30 | 13 |
| | 15 | 0.027 | 45 | 9 |
| | 20 | 0.020 | 60 | 7 |
| | 30 | 0.013 | 90 | 4 |
| | 40 | 0.010 | 120 | 3 |
| | 50 | 0.008 | 150 | 3 |

The accuracy in determining snow water equivalent over courses depends on the nonuniformity of snow distribution and the number of measurement points. Studies show that the errors in determining maximum snow water equivalent in northern and northwestern areas of European USSR amount to 5-6 %, and in central and southern areas to 7-8%.

## 14. KAMCHATKA.

Vinogradov (1964). The eastern littoral includes the zone situated along the eastern coast of the Kamchatka peninsula. The winter period is characterized by relatively high air temperatures and heavy precipitation. The latter is often accompanied by strong winds of 29-40 m/s. As a rule, the determination of snow cover is carried out simultaneously throughout the entire region: in 1960 it took place during the last ten days of October. In the southern area of the region, within the Avachin depression, the nonuniformity in distribution of snow cover characteristic of Kamchatka is observed. The smallest depth of snow cover during the period of maximum accumulation is recorded in the area of the villages Yelizovo and Koryaki (50-60 cm). At the same time, the basin among the medium-height ridges where the village of Paratunka is located is characterized by the deepest snow cover, reaching 220-240 cm in hard birch forest and 160-170 cm in open areas without forestation. The density of the snow gradually increases from 0.10 to 0.12 g/cm$^3$ in the beginning of the winter to 0.35 to 0.40 g/cm$^3$ at the time of maximum snow accumulation.

On the upper relief layer, on plowed land, accumulation occurs extremely slowly. A significant portion of the snow is carried away by wind, during the first ten days of December the depth of snow cover was 29 cm. A snow mass section consisted of two strata: freshly fallen snow, and weakly crystallized, finely granulated snow. At the same time, in areas covered with an undergrowth of hard birch, the depth of snow cover reached 57 cm at a density of 0.20 g/cm$^3$. In hard birch thickets, the depth of snow cover was 168 cm, which was the maximum amount of snow accumulation on a flat surface in the area of Petropavovsk. The density of the snow is 0.29 g/cm$^3$, and the water supplies in the snow mass, 487 mm. In an open area occupied by a field, the depth of snow cover was 90 cm. As a result of great wind compaction, density was 0.31 g/cm$^3$, and the water supplies, 279 mm.

Wind conditions exert a great influence on the distribution of snow cover. In areas where prevailing wind is strong (more than 29 m/s) and northeasterly, the most snow-covered slope is that with southern exposure, where accumulation takes place more extensively due to the snow masses blown from the ridge. The maximum snow cover was recorded in the middle of March, when its depth on a southern slope was 128 cm, its density 0.31 $g/cm^3$, and its water supplies 396.8 cm.

Snow cover on flat offshore bars is subject to extreme variation and shifting. These areas are characterized by extremely deep snow cover; in the period of maximum snow accumulation it has a depth of 52 cm. As a result of strong winds often encountered on the littoral, the density of snow cover approaches its maximum in February, and in the middle of March it was 0.34 $g/cm^3$. In a snow mass section a series of strata of finely granulated, friable snow and hard-frozen snow was observed. In open areas of the maritime plain, in the base of a snow section taken during the beginning of April was observed ice similar to that on the gulf of the sea. During the period of maximum snow accumulation in the middle of March, the depth of snow cover on the surface of the gulf was 38 cm, and in open areas of the maritime plain, 75 cm. Such a difference may be explained by the more extensive transfer of snow on the surface of the gulf. The maximum snow cover was found in occasional groups of willow that favored the accumulation of snow. The density of snow in the willow clusters was 0.30 $g/cm^3$, somewhat lower than that in open areas. Dissipation of the snow cover begins during the end of May.

During the period of maximum snow accumulation (from the second half of February to the second half of March) the greatest differences in depth of snow cover were to be found in the different standard areas. The maximum depth of snow cover, 182 cm, was recorded on a slope of north-northwestern exposure with an angle of inclination of up to 20° under cover of a hard birch forest. The smallest depth was observed on the flat, open surface of the Kamchatka River, and was equal to 155 cm. Density of the snow cover continued to increase, a certain degree of stabilization being observed in open areas at 0.30-0.31 $g/cm^3$. During this time the density in areas of forestation increased from 0.20 to 0.30 $g/cm^3$. Water supplies increased constantly as a function of the depth and density of the snow cover; although during the period of snow accumulation the water supplies in open areas were lower than those in forested areas, during the period of maximum snow accumulation the situation was reversed, and in open areas they were somewhat higher.

The structure of the snow mass in the period of maximum snow accumulation in the different standard areas had certain common features. In open areas, a layer of buried snow from snowstorms was observed that was absent under cover of forest. In the period of snowfall (April-May), extensive fusion of the snow crystals and a decrease in the depth of snow cover occurred as a result of average daily temperatures exceeding 0°C. In open areas the snow cover dissipated by the beginning of June. Considerably slower snow thaw occurred under cover of hard birch forest, where dissipation of the snow cover occurred during the second half of June. The highest values of snow cover density, 0.45 $g/cm^3$, were recorded for open areas; in hard birch forest the density did not exceed 0.43 $g/cm^3$. During the second half of April complete fusion of the snow granules occurs, and

the snow mass acquires a uniform structure. In the beginnning of May, throughout its profile, regardless of the depth of snow cover, the snow mass consists of fused snow; at its base is observed a layer of water.

The climate of the Esso region has features of continental nature, expressed in terms of a relatively dry and hot summer and a cold winter. Average monthly air temperatures are near or below -15°C. In December and January it is not uncommon for the air temperature to fall below -40°C at night. Wind conditions have no effect on redistribution of snow, since weak winds with an average velocity of 2-4 m/s prevail. The maximum wind velocities do not exceed 10 m/s, and these occur only infrequently and are of short duration. On October 20 the depth of snow cover was 12 cm at a density of 0.12 g/cm$^3$. Accumulation over the course of the first month of its existence took place extremely slowly, and on November 20 in open areas it had a depth of 16 cm at a density of 0.15 g/cm$^3$.

The accumulation of snow cover in the Esso region occurred relatively uniformly and concluded in the middle of January. By this time the depth of snow cover had stabilized, and subsequently it underwent very little change prior to the beginning of snow thaw. During the course of the winter period the snow cover in forested areas is 10 cm greater than that in open areas, this difference remaining fairly constant. In forested areas constant accumulation of snow cover occurred until January 20. Subsequently, during the course of February and March, no increase in depth is observed, but fluctuations of up to 7 cm are recorded due to wind effects. By January 20 the depth of snow cover was 58 cm at a density of 0.17 g/cm$^3$. Within a month its depth grew to 63 cm, and its density also increased to 0.19 g/cm$^3$. March was characterized by a decrease in the depth of snow cover and stabilization of its density at 0.21-0.22 g/cm$^3$. During the period of maximum snow accumulation the depth of snow cover reached 71 cm, which is the maximum figure for this region. The density of snow cover at this point was 0.23 g/cm$^3$. Subsequently, during snow thaw the density increases to 0.26 g/cm$^3$ as a result of dampening of the snow mass.

In open areas accumulation of snow cover occurred in a manner similar to that described during February and March. Extensive accumulation does not occur, but the depth of snow cover does not remain constant; it increases slightly. The absence of strong winds capable of transferring snow results in a relatively uniform distribution of snow cover. In the period of maximum snow accumulation, the snow cover in open areas has a depth of 59 cm. The density of snow cover remains constant at 0.22 g/cm$^3$ as of the beginning of February. During snow thaw the density increases to 0.24 g/cm$^3$.

In the middle reaches of the Anavgaj River the right edge of the gently sloping valley rises to the planated lava surface of the Central Range in the area of the Anaun volcano. Here a larch forest extends up to the upper boundary of the forest belt, and a belt of hard birch occurs. The snow cover is friable and occurs relatively uniformly. On a slope of eastern exposure with an angle of inclination of 10°, under cover of the larch forest the depth of snow cover is 82 cm at a density of 0.30 g/cm$^3$. Stable snow cover was formed on October 29, and its principal accumulation occurred during November and the first half of December. On December 20 in

a level, open area the depth of snow cover was 54 cm at a density of 0.25 g/cm$^3$. Within the accumulation period the depth of snow cover remains fairly constant. During the first ten days of February, after almost two months' existence of snow cover, its depth underwent hardly any change. On the surface of the hollow, the depth of snow cover was 54 cm at a density of 0.26 g/cm$^3$.

During the period of maximum snow accumulation, the most snow covered types of relief are depressed areas. In the hollow, the depth of snow cover was 72 cm at a density of 0.22 g/cm$^3$. Elevated areas exposed to the wind had depths of snow cover approximately half as great; on the weakly defined divide it was 47 cm, at a density of 0.25 g/cm$^3$. Snow melting occurred at a reduced rate in April and very rapidly in May. On the level surface of the divide, from April 20 to April 30 the depth of snow cover decreased from 31 to 24 cm, and by May 10 no snow cover remained. In the hollow snow thaw occurred more slowly, and during the same period the snow cover decreased respectively from 58 to 49 cm and from 49 to 8 cm.

In the area of the settlement Ust-Bolsheretsk snow cover existed for 194 days in 1960-61. The maximum depths of snow cover in depressed areas were 72 cm, and in elevated areas, 47 cm. As a result of wind action the density of snow cover approaches its maximum, registering 0.25 g/cm$^3$, in the middle of December. The area of the settlement Sobolevo, located to the north of Ust-Bolsheretsk, also has a plain relief. Stable snow cover was formed on October 20 after prolonged snowfall. Formation and accumulation occurred at a fairly rapid pace: on October 31 the depth of snow cover was 29 cm at a density of 0.17-0.18 g/cm$^3$, and its distribution was uniform. By November 20, the depth of snow cover had increased to 42 cm in open areas and 47 cm in hard birch forest; its density remained unchanged. Subsequently, a slower increase in the depth of snow cover takes place, but its density increases rapidly. On December 20 the depth of snow cover in open areas is 58 cm at a density of 0.25 g/cm$^3$, and in forested areas, 64 cm at density of 0.22 g/cm$^3$. A fairly constant increase in the depth of snow cover occurs until the middle of January.

In the period of maximum snow accumulation, the most snow-covered areas are those with forestation. On the level of a terrace covered with hard birch forest was recorded the maximum depth of snow cover for this area - 92 cm, at a density of 0.26 g/cm$^3$. A level surface with herbaceous grassland has a depth of snow cover of 77 cm at a density of 0.27 g/cm$^3$. Snow thaw occurs rapidly. In open areas the snow cover dissipated on May 10, and in forest, on May 17. Snow cover in the area of the settlement Sobolevo existed during the winter period 1960-61 for 202 days in open areas and 209 days in forested areas. The maximum depth of snow cover on a level surface covered by hard birch forest was 92 cm, and in open areas, 77 cm. The area of the settlement Sobolevo is characterized by greater snow cover than the area of Ust-Bolsheretsk, located to the south. In northwestern Kamchatka a decrease in depth of snow cover occurs from south to north.

The area of the settlement Tigil is more distant from the Sea of Okhotsk than the areas of the western littoral described above and differs from them by virtue of its hilly and ridged relief. Snow cover was formed on October 10. Its accumulation occurred during the second ten days of October. In its uniform occurrence a depth of snow cover was observed of

27 cm at a density of 0.11 $g/cm^3$. In November, during an increase in depth of snow cover, differences were recorded in its distribution in different areas: in fields, 43 cm, and under cover of hard birch forest, 50 cm. Accumulation of the snow cover in this area concluded in the middle of February.

## 15. URAL MOUNTAINS.

Khodakov (1967). The Ural Mountains to the north of 60° northern latitude are still largely unsettled, and the hydrometeorology of the region has received little study. However, its natural resources, especially it useful mineral and hydraulic power resources, promise this region an important role in the economics of the country in the near future. National economic development requires a thorough knowledge of the physical and geographical conditions of this region.

The rate of snowstorm transport determines to a considerable extent the structure and properties of the snow. In the bald mountain zone a large portion of its mass is made up of finely- and medium-granulated, dense snow formed from densely packed, fine particles of snowstorm snow. The density of these types of snow during the second half of the winter is usually 0.35-0.42 $g/cm^3$. If the depth of the snow is slight, a layer forms in the lower portion of its depth in which it become friable. In deep snow masses the density increases continuously with increasing depth, reaching 0.55-0.58 $g/cm^2$ at a depth of 10 m. In the forest zone, finely granulated snow with a density of 0.25 - 0.30 $g/cm^3$ is observed only in the upper third of a section. The remainder of the section is occupied by coarsely granulated snow and deep-seated hoarfrost with a density of 0.15-0.25 $g/cm^2$. The very dense snow of the unforested Urals has exceptional mechanical strength. The rupture plasticity for dense, finely granulated snow is 120-250 $g/cm^3$, and for wind panels (density 0.42-0.45 $g/cm^3$), up to 600 $g/cm^2$; shear plasticity is 500-1500 $g/cm^2$ and up to 5600 $g/cm^2$; the viscosity coefficient is $1 \times 10^{13}$ poise and $0.8 \times 10^{12}$ poise, respectively. The high strength of bald mountain zone snow produces relatively weak development of avalanche activity. Winter avalanches are small in volume, consist of fresh snowstorm snow, and are confined to steep, leeward slopes of mountain plateaus. In the spring, when the snow warms up and melts a little, its strength falls sharply, and the number of avalanches increases.

Our measurements have shown that the coefficient of thermal conductivity of the snow, obtained from observations made on location, corresponds closely to that calculated by the Ab'el's equation. This means that at the snow density 0.2 $g/cm^3$ characteristic of the forested zone, the thermal conductivity at equal snow strengths and heat flows is one-fourth that at the density 0.4 $g/cm^3$ characteristic of the bald mountain zone. Since the balance of the surface heat balance varies gradually from south to north, it is evidently possible only by means of a sharp increase in the snow's thermal conductivity to explain the observed sharp increase in strength of permafrost in the unforested zone.

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## APPENDIX B

**AVERAGE 5-MONTH (NOVEMBER THROUGH MARCH) WIND SPEED (M/S) FOR STATIONS IN THE SOVIET UNION*.**

| Station | Coordinates Lat(N) | | Long(E) | | Elevation (m) | No. months Temp. < 0°C | Ave. 5-mo.** (Nov-Mar) wind speed (m/s) |
|---|---|---|---|---|---|---|---|
| Abakan | 53° | 43' | 91° | 26' | - | - | 2.6 |
| Abramovskiy | 66 | 25 | 43 | 15 | 24 | - | 7.0 |
| Achinsk | 56 | 18 | 90 | 31 | 235 | 5 | 4.8 |
| Adamovka | 51 | 31 | 59 | 57 | 285 | 5 | 3.7 |
| Ado Tymova | 51 | 08 | 142 | 40 | 64 | 5 | 1.4 |
| Agata | 66 | 55 | 93 | 28 | 244 | 7 | 1.9 |
| Aginskoye | 55 | 15 | 94 | 55 | - | - | 2.5 |
| Ak-Baytal | 43 | 09 | 64 | 20 | 232 | 3 | 3.6 |
| Aksenovo Zilovskoye | 53 | 04 | 117 | 29 | 707 | 7 | 1.6 |
| Ak-Tel | 51 | 10 | 93 | 25 | - | - | 1.0 |
| Aktyubinsk | 58 | 37 | 57 | 09 | 227 | 5 | 4.1 |
| Aldan | 58 | 17 | 125 | 22 | 682 | 7 | 3.0 |
| Aleksandrov-Gay | 50 | 09 | 48 | 33 | 25 | 5 | 5.0 |
| Aleksandrovsk Sakhalinskiy | 50 | 54 | 142 | 10 | 30 | 6 | 4.6 |
| Aleksandrovskoye | 60 | 26 | 77 | 52 | 60 | 7 | 3.4 |
| Alma-Ata | 43 | 14 | 76 | 56 | 847 | 3 | 0.9 |
| Amangel'dy | 50 | 08 | 65 | 14 | 142 | 5 | 4.3 |
| Amderma | 69 | 46 | 61 | 41 | 53 | 7 | 8.5 |
| Anadyr | 64 | 47 | 177 | 34 | 61 | 7 | 7.9 |
| Anavgay | 56 | 06 | 158 | 53 | - | 7 | 2.0 |
| Anuchino | 43 | 58 | 133 | 04 | 189 | 5 | 2.0 |
| Aral'sk | 46 | 47 | 61 | 40 | 56 | 5 | 5.2 |
| Arkhangel'sk | 64 | 35 | 40 | 30 | 13 | - | 4.5 |
| Arkhara | 49 | 25 | 130 | 07 | 142 | 5 | 2.7 |
| Arshan | 51 | 54 | 102 | 27 | - | 6 | 1.2 |
| Artemovsk | 54 | 21 | 93 | 26 | 472 | 6 | 1.0 |
| Astrakhan' | 46 | 16 | 48 | 02 | 18 | 3 | 4.7 |
| Atbasar | 51 | 49 | 68 | 22 | 308 | 5 | 5.5 |
| Ayaguz | 47 | 56 | 80 | 23 | 659 | 5 | 3.9 |
| Ayan | 56 | 27 | 138 | 09 | 9 | 6 | 2.8 |
| Bakchar | 57 | 01 | 82 | 05 | - | 6 | 3.8 |
| Bakhta | 62 | 28 | 89 | 00 | - | - | 2.8 |
| Balkhash | 46 | 54 | 75 | 00 | 423 | 5 | 5.3 |
| Balakhta | 55 | 23 | 91 | 37 | - | - | 2.9 |
| Barabinsk | 55 | 22 | 78 | 24 | 120 | 5 | 5.6 |
| Barouzin | 53 | 37 | 109 | 38 | 486 | 6 | 2.1 |
| Barnaul | 53 | 20 | 83 | 42 | 196 | 5 | 5.8 |
| Batamay | 63 | 31 | 129 | 26 | 78 | 7 | 1.8 |
| Baturino | 57 | 48 | 85 | 12 | - | 6 | 3.1 |
| Bayevo | 53 | 17 | 80 | 46 | - | 5 | 4.2 |
| Baykit | 61 | 41 | 96 | 25 | - | - | 0.7 |
| Bektan Ata | 47 | 27 | 74 | 49 | 616 | 5 | 5.9 |
| Bel'tsy | 47 | 46 | 27 | 56 | - | - | 3.4 |
| Berezovo | 63 | 56 | 65 | 03 | 20 | 7 | 3.4 |

*See text for various data sources.

**Compilation of a uniform period and/or length of record was not possible. Records dating from 1948 to 1971 were mostly included in the survey, and ranged in length of from 3 to more than 15 years.

| Station | Coordintes Lat (N) | | Long(E) | | Elevation (m) | No. Months Temp. < 0°C | Ave. 5-mo. (Nov-Mar) wind speed (m/s) |
|---|---|---|---|---|---|---|---|
| Betpak-Dala | 46° | 01' | 70° | 12' | - | 5 | 4.4 |
| Big Diomede Island | 65 | 47 | 169 | 05(W)* | 39 | 7 | 5.7 |
| Birilyussy | 57 | 07 | 90 | 32 | 167 | 5 | 2.6 |
| Biysk | 52 | 34 | 85 | 15 | 230 | 5 | 4.9 |
| Blagoveshchensk | 50 | 16 | 127 | 32 | 136 | 5 | 2.8 |
| Boguchar | 49 | 56 | 40 | 34 | 82 | 4 | 3.3 |
| Bogopol' | 44 | 15 | 135 | 28 | 50 | 5 | 2.8 |
| Bogotol | 56 | 10 | 89 | 35 | - | 5 | 4.8 |
| Bogorodskoye | 52 | 23 | 140 | 28 | 31 | 6 | 2.2 |
| Boguchany | 58 | 23 | 97 | 29 | 134 | 6 | 2.8 |
| Bol'shaya Murta | 56 | 55 | 93 | 07 | - | - | 2.2 |
| Bol'shoy Porog | 65 | 39 | 90 | 05 | - | - | 1.9 |
| Bol'shenarymskoye | 49 | 12 | 84 | 31 | 404 | 5 | 1.4 |
| Bolgrad | 45 | 40 | 28 | 37 | 81 | 2 | 4.2 |
| Bolotnoye | 55 | 41 | 84 | 23 | - | 5 | 4.5 |
| Bomnak | 54 | 43 | 128 | 50 | 352 | 7 | 2.3 |
| Borovichi | 58 | 24 | 33 | 55 | - | - | 3.5 |
| Borzya | 50 | 23 | 116 | 31 | 684 | 6 | 2.6 |
| Bratsk | 56 | 21 | 101 | 55 | 327 | 7 | 2.2 |
| Brest | 52 | 07 | 23 | 41 | 143 | 3 | 3.9 |
| Bryansk | 53 | 20 | 34 | 14 | 162 | 5 | 5.0 |
| Bukhta Pronchishchevoy | 75 | 40 | 113 | 11 | - | 7 | 4.6 |
| Bukhta Solnechnaya | 78 | 10 | 102 | 50 | - | - | 6.4 |
| Bukhta Ugol'naya | 63 | 03 | 179 | 19 | - | 7 | 10.6 |
| Buolkalakh | 72 | 56 | 119 | 50 | - | 7 | 5.8 |
| Buor-Yuryakh | 68 | 11 | 145 | 55 | - | 7 | 1.2 |
| Burlyu Tobe | 46 | 35 | 79 | 06 | 351 | 5 | 3.2 |
| Buynaksk | 42 | 49 | 47 | 07 | 472 | 2 | 3.5 |
| Byssa | 52 | 21 | 131 | 17 | - | 6 | 1.0 |
| Chadan | 51 | 22 | 91 | 27 | - | 6 | 1.2 |
| Chadopets | 58 | 40 | 98 | 51 | 150 | 7 | 2.3 |
| Chara | 56 | 55 | 118 | 22 | 703 | 7 | 0.6 |
| Charkov | 53 | 43 | 90 | 22 | 524 | 5 | 2.9 |
| Chekunda | 50 | 49 | 132 | 10 | 234 | 5 | 1.0 |
| Chelyabinsk | 55 | 09 | 61 | 24 | 230 | 5 | 4.2 |
| Chemdal'sk | 59 | 38 | 103 | 20 | - | - | 1.1 |
| Cherdyn' | 60 | 24 | 56 | 31 | 206 | 6 | 4.5 |
| Cheremkhovo | 53 | 09 | 103 | 05 | - | 6 | 2.2 |
| Cherepovets | 59 | 07 | 37 | 57 | 131 | 5 | 5.3 |
| Chernovtsy | 48 | 18 | 25 | 56 | - | 3 | 3.0 |
| Chimbay | 42 | 57 | 59 | 49 | 66 | 3 | 2.7 |
| Chirgalandy | 50 | 36 | 97 | 15 | - | - | 0.7 |
| Chita | 52 | 01 | 113 | 20 | 684 | - | 1.5 |
| Chokurdakh | 70 | 37 | 147 | 53 | 47 | 7 | 4.3 |
| Chul'man | 56 | 50 | 124 | 52 | 664 | 7 | 1.1 |
| D'elind'e | 65 | 15 | 135 | 36 | - | 7 | 0.7 |

| Station | Coordintes Lat (N) | | Long(E) | | Elevation (m) | No. Months Temp. < 0°C | Ave. 5-mo. (Nov-Mar) wind speed (m/s) |
|---|---|---|---|---|---|---|---|
| Dambuki | 54° | 21' | 127° | 38' | 270 | 6 | 2.0 |
| Dikson | 73 | 30 | 80 | 25 | 18 | 7 | 7.9 |
| Dnepropetrovsk | 48 | 27 | 35 | 03 | 142 | 4 | 4.4 |
| Dno | 57 | 50 | 29 | 59 | - | - | 3.5 |
| Dolgiy Most | 56 | 45 | 96 | 48 | 256 | 7 | 2.4 |
| Dolinsk | 47 | 20 | 142 | 48 | 42 | 5 | 3.6 |
| Dudinka | 69 | 24 | 86 | 15 | 28 | 7 | 5.3 |
| Duki | 51 | 43 | 135 | 54 | 131 | 5 | 1.2 |
| Dzerzhinskoye | 56 | 50 | 95 | 13 | - | 5 | 2.3 |
| Dzhalal Abad | 40 | 55 | 72 | 57 | 771 | 1 | 1.6 |
| Dzhambeyty | 50 | 15 | 52 | 34 | 34 | 5 | 5.8 |
| Dzhambul | 42 | 51 | 71 | 23 | 641 | 3 | 3.1 |
| Dzhardzhan | 68 | 44 | 124 | 00 | 46 | 7 | 3.1 |
| Dzhezkazgan | 47 | 48 | 67 | 43 | 345 | 5 | 4.1 |
| Egvekinot | 66 | 21 | 179 | 07(W) | - | 7 | 6.3 |
| Ekimchan | 53 | 04 | 132 | 56 | 491 | 7 | 0.8 |
| El'gen | 62 | 48 | 150 | 41 | 303 | 7 | 1.1 |
| El'ton | 49 | 08 | 46 | 51 | 11 | 4 | 5.1 |
| Erzin | 50 | 15 | 95 | 10 | - | - | 1.3 |
| Fort Shevchenko | 44 | 33 | 50 | 15 | 20 | 1 | 6.9 |
| Gdov | 58 | 46 | 27 | 48 | - | - | 5.0 |
| Gizhiga | 62 | 03 | 160 | 30 | 10 | 7 | 5.5 |
| Glazov | 58 | 09 | 52 | 40 | - | 5 | 3.7 |
| Gol'chikna | 71 | 43 | 83 | 36 | 10 | 7 | 6.4 |
| Gor'kiy | 56 | 20 | 43 | 59 | - | 5 | 5.8 |
| Gora Dogdynyn | 63 | 36 | 104 | 11 | 769 | 7 | 2.3 |
| Goryachinsk | 52 | 59 | 108 | 18 | - | 6 | 4.0 |
| Goryun | 51 | 16 | 136 | 35 | 78 | 6 | 2.2 |
| Grossevichi | 47 | 58 | 139 | 32 | 36 | 5 | 4.3 |
| Groznyy | 43 | 21 | 45 | 41 | 124 | 2 | 2.6 |
| Gudauri | 42 | 28 | 44 | 28 | 2133 | - | 3.1 |
| Guga | 52 | 42 | 137 | 32 | 50 | 6 | 0.7 |
| Gur'yev | 47 | 07 | 51 | 51 | 21 | 3 | 5.7 |
| Gyda | 70 | 56 | 78 | 25 | 4 | 7 | 6.2 |
| Idrinskoye | 54 | 21 | 92 | 07 | - | - | 2.3 |
| Icha | 55 | 42 | 155 | 38 | 4 | 5 | 5.4 |
| Ichera | 58 | 32 | 109 | 47 | - | 7 | 1.5 |
| Idritsa | 56 | 19 | 28 | 54 | 139 | 5 | 4.5 |
| Igarka | 67 | 28 | 86 | 34 | 29 | 7 | 4.8 |
| Ika | 59 | 18 | 106 | 24 | - | 7 | 1.4 |
| Il'inskiy | 47 | 59 | 142 | 12 | 18 | 5 | 5.2 |
| Ilirney | 67 | 20 | 168 | 14 | 425 | 7 | 1.5 |
| Irgiz | 48 | 37 | 61 | 16 | 114 | 5 | 4.7 |
| Irkutsk | 52 | 16 | 104 | 20 | 468 | - | 2.2 |
| Isit | 60 | 49 | 125 | 19 | 118 | 7 | 2.4 |
| Ivano-Frankovsk | 48 | 54 | 24 | 42 | 276 | 3 | 3.7 |

| Station | Coordinates Lat(N) | | Long(E) | | Elevation (m) | No. months Temp. < 0°C | Ave. 5-mo. (Nov-Mar) wind speed (m/s) |
|---|---|---|---|---|---|---|---|
| Ivanovo | 57° | 10' | 40° | 58' | 138 | 5 | 5.1 |
| Ivdel' | 60 | 41 | 60 | 26 | 100 | 6 | 1.9 |
| Kachug | 53 | 58 | 105 | 52 | - | 7 | 1.9 |
| Kagul | 45 | 54 | 28 | 11 | - | - | 4.2 |
| Kaliningrad | 54 | 42 | 20 | 37 | 27 | 3 | 4.5 |
| Kalmykovo | 49 | 03 | 51 | 52 | 4 | 4 | 4.9 |
| Kamenka | 58 | 33 | 95 | 51 | - | 5 | 2.4 |
| Kamen Rybolov | 44 | 43 | 132 | 04 | 75 | 5 | 3.4 |
| Kamen' na Obi | 53 | 47 | 81 | 20 | - | 5 | 5.5 |
| Kamenskoye | 62 | 29 | 166 | 13 | - | 7 | 6.1 |
| Kandalaksha | 67 | 08 | 32 | 26 | 15 | 6 | 4.1 |
| Kanevka | 67 | 08 | 39 | 40 | - | - | 2.6 |
| Kanin Nos | 68 | 39 | 43 | 18 | 4 | 6 | 9.4 |
| Kansk | 56 | 13 | 95 | 41 | 203 | 5 | 3.6 |
| Kapustin Yar | 48 | 35 | 45 | 43 | 9 | 4 | 4.3 |
| Kara-Kul'-Bulak | 46 | 47 | 64 | 40 | - | 5 | 4.4 |
| Karaganda | 49 | 48 | 73 | 08 | 555 | 5 | 4.9 |
| Karaginskiy | 59 | 00 | 163 | 55 | 6 | 6 | 7.9 |
| Kara-Kem | 52 | 23 | 92 | 24 | - | - | 2.6 |
| Karam | 55 | 09 | 107 | 37 | - | 7 | 1.3 |
| Kargasok | 59 | 03 | 80 | 53 | - | 7 | 4.3 |
| Karsakpay | 47 | 50 | 66 | 45 | 488 | 5 | 4.1 |
| Karatuz | 53 | -36 | 92 | 53 | - | - | 1.8 |
| Karaul | 70 | 06 | 83 | 08 | - | - | 7.1 |
| Kaunas | 54 | 53 | 23 | 53 | 75 | 4 | 4.4 |
| Kaynar | 49 | 11 | 77 | 25 | - | 5 | 4.2 |
| Kazach'ye | 70 | 45 | 136 | 13 | 21 | 7 | 3.5 |
| Kazachinskoye Exp. Field | 57 | 42 | 93 | 17 | 93 | 7 | 2.4 |
| Kazachinskoye | 56 | 42 | 107 | 36 | - | 7 | 1.3 |
| Kazalinsk | 45 | 46 | 62 | 07 | 68 | 3 | 3.7 |
| Kazan' | 55 | 47 | 49 | 11 | 64 | 5 | 5.3 |
| Kedon | 64 | 08 | 159 | 14 | 682 | 7 | 1.1 |
| Kellog | 62 | 29 | 86 | 19 | - | 7 | 2.5 |
| Kem' | 64 | 59 | 34 | 48 | 9 | 6 | 5.3 |
| Kemerovo | 55 | 23 | 86 | 04 | 153 | 5 | 5.0 |
| Kerbo | 62 | 44 | 101 | 06 | - | - | 0.7 |
| Kezhma | 58 | 59 | 101 | 09 | - | 5 | 2.5 |
| Khabarovsk | 48 | 31 | 135 | 10 | 71 | 5 | 4.4 |
| Khadama | 53 | 57 | 98 | 51 | - | 7 | 1.4 |
| Khanty Mansiysk | 60 | 58 | 69 | 04 | 39 | 6 | 4.2 |
| Khar'kov | 49 | 56 | 36 | 17 | 152 | 4 | 4.7 |
| Kharlovka | 68 | 47 | 37 | 20 | 12 | 6 | 8.8 |
| Khatanga | 71 | 58 | 102 | 30 | 24 | 7 | 4.5 |
| Khatyrka | 62 | 03 | 175 | 16 | 152 | 7 | 9.0 |
| Khilok | 51 | 21 | 110 | 30 | 801 | 7 | 2.2 |
| Khmel'nitskiy | 49 | 24 | 26 | 59 | 195 | 4 | 4.1 |

| Station | Coordinates Lat(N) | | Long(E) | | Elevation (m) | No. months Temp. < 0°C | Ave. 5-mo. (Nov-Mar) wind speed (m/s) |
|---|---|---|---|---|---|---|---|
| Kholm | 57° | 09' | 31° | 11' | - | - | 3.4 |
| Khonuu | 66 | 27 | 143 | 14 | 160 | 7 | 0.3 |
| Khorog | 37 | 30 | 71 | 30 | 2080 | 3 | 0.5 |
| KhosedaKhard | 67 | 02 | 59 | 24 | 81 | 7 | 4.4 |
| Kingisepp | 58 | 15 | 22 | 28 | - | 4 | 6.3 |
| Kirensk | 57 | 46 | 108 | 08 | 256 | 7 | 2.2 |
| Kirov | 58 | 39 | 49 | 37 | 164 | 5 | 4.9 |
| Kirovograd | 48 | 29 | 32 | 15 | 148 | 3 | 5.0 |
| Kirovsk | 67 | 37 | 33 | 40 | - | - | 3.4 |
| Kirovskiy | 45 | 06 | 133 | 30 | - | 5 | 2.0 |
| Kiselevsk | 54 | 00 | 86 | 39 | - | 5 | 3.8 |
| Kishinev | 47 | 00 | 28 | 50 | - | - | 4.4 |
| Kiyev (Kiev) | 50 | 24 | 30 | 27 | 178 | 4 | 4.8 |
| Kochenga | 55 | 55 | 104 | 06 | - | 7 | 1.0 |
| Kochumdek | 64 | 24 | 92 | 48 | 110 | 7 | 1.5 |
| Kokchetav | 53 | 17 | 69 | 21 | 228 | 5 | 5.8 |
| Kolpashevo | 58 | 18 | 82 | 54 | 75 | 7 | 3.7 |
| Kommunar | 54 | 20 | 89 | 18 | - | - | 4.3 |
| Korennov | 73 | 33 | 107 | 10 | - | 7 | 5.0 |
| Korf | 60 | 21 | 166 | 00 | - | 7 | 7.3 |
| Koschagyl | 46 | 48 | 53 | 55 | - | 4 | 7.2 |
| Kosh Agach | 50 | 01 | 88 | 44 | 1758 | 7 | 0.9 |
| Kosistyy | 73 | 38 | 109 | 40 | - | - | 5.5 |
| Kosukhino | 71 | 19 | 149 | 23 | - | 7 | 4.6 |
| Kovdor | 67 | 34 | 30 | 24 | - | - | 2.9 |
| Kozyrevsk | 56 | 03 | 159 | 51 | - | 5 | 2.6 |
| Kraskino | 42 | 43 | 130 | 47 | 11 | 5 | 4.5 |
| Krasnodar | 45 | 02 | 39 | 09 | 32 | 1 | 3.7 |
| Krasnoufimsk | 56 | 37 | 57 | 45 | 220 | 5 | 3.3 |
| Krasnoyarsk | 56 | 01 | 92 | 53 | 193 | 5 | 3.7 |
| Krasnozerskoye | 53 | 59 | 79 | 14 | - | 5 | 4.9 |
| Krasnyy Chikoy | 50 | 27 | 108 | 45 | 769 | 6 | 1.0 |
| Kreshchenka | 55 | 51 | 80 | 02 | - | 6 | 3.9 |
| Kumara | 51 | 34 | 126 | 43 | 178 | 5 | 1.7 |
| Kunda | 59 | 30 | 26 | 32 | - | 4 | 5.6 |
| Kupino | 54 | 22 | 77 | 18 | 120 | 5 | 5.8 |
| Kuragino | 53 | 53 | 92 | 40 | - | - | .7 |
| Kureyka | 66 | 29 | 87 | 09 | - | - | 3.3 |
| Kurgan | 55 | 28 | 65 | 24 | 78 | 5 | 4.3 |
| Kursk | 51 | 39 | 36 | 11 | 167 | 5 | 4.9 |
| Kustanay | 53 | 13 | 63 | 37 | 171 | 5 | 4.3 |
| Kuybyshev | 53 | 15 | 50 | 27 | 43 | 5 | 4.4 |
| Kyakhta | 50 | 22 | 106 | 27 | 789 | - | 1.2 |
| Kuz'movka | 62 | 19 | 92 | 02 | - | - | 1.3 |
| Kuzomen' | 66 | 17 | 36 | 54 | - | - | 6.1 |
| Kyra | 49 | 34 | 111 | 58 | 887 | - | 1.9 |

| Station | Coordinates Lat(N) | | Long(E) | | Elevation (m) | No. Months Temp. < 0°C | Ave. 5-mo. (Nov-Mar) wind speed (m/s) |
|---|---|---|---|---|---|---|---|
| Kyusyur | 70° | 41' | 127° | 24' | 29 | 7 | 3.3 |
| Kyzyl | 51 | 42 | 94 | 27 | 640 | 7 | 0.9 |
| L'vov | 49 | 49 | 23 | 57 | 324 | 3 | 3.8 |
| Leninakan | 40 | 47 | 43 | 50 | 1528 | 4 | 1.2 |
| Leningrad | 59 | 56 | 30 | 16 | 6 | 5 | 3.2 |
| Leushi | 59 | 37 | 65 | 47 | 82 | 6 | 3.8 |
| Lodeynoye Pole | 60 | 44 | 33 | 33 | - | - | 4.5 |
| Lokshak | 54 | 44 | 130 | 77 | 84 | 7 | 1.0 |
| Lomonosovo | 75 | 37 | 91 | 20 | - | - | 7.1 |
| Losinoborskaya | 58 | 27 | 89 | 28 | - | - | 2.5 |
| Loukhi | 66 | 04 | 33 | 04 | - | 6 | 3.2 |
| Lovozero | 68 | 00 | 35 | 04 | - | - | 3.3 |
| Lubny | 50 | 01 | 33 | 02 | 164 | - | 3.9 |
| Lukoyanov | 55 | 02 | 44 | 30 | 206 | 5 | 4.0 |
| Magadan | 59 | 35 | 150 | 47 | 118 | 7 | 5.7 |
| Magnitogorsk | 53 | 21 | 59 | 05 | 381 | 5 | 4.8 |
| Maksimkin Yar | 58 | 41 | 86 | 49 | 104 | 7 | 3.1 |
| Malinovo | 45 | 25 | 134 | 16 | - | 5 | 2.7 |
| Mama | 58 | 18 | 112 | 54 | - | 7 | 2.8 |
| Mamakan | 57 | 48 | 114 | 01 | - | 7 | 1.7 |
| Markovo | 64 | 41 | 170 | 25 | 32 | 7 | 3.1 |
| Marresale | 69 | 43 | 66 | 49 | 11 | 7 | 6.8 |
| Maslyanino | 54 | 20 | 84 | 13 | - | - | 3.2 |
| Maysk | 57 | 47 | 77 | 17 | 114 | 6 | 3.3 |
| Melitopol' | 46 | 50 | 35 | 22 | 39 | 2 | 5.6 |
| Mezen' | 65 | 52 | 44 | 13 | 14 | 6 | 4.8 |
| Minsk | 53 | 52 | 27 | 32 | 234 | 4 | 4.6 |
| Mogocha | 53 | 44 | 119 | 47 | 619 | 7 | 1.3 |
| Monchegorsk | 67 | 56 | 32 | 58 | - | - | 4.4 |
| Mondy | 51 | 40 | 100 | 59 | 1304 | 7 | 2.5 |
| Moscow | 55 | 45 | 37 | 34 | 156 | 5 | 4.0 |
| Motygino | 58 | 11 | 94 | 40 | - | - | 2.3 |
| Mozdok | 43 | 44 | 44 | 40 | 132 | 3 | 2.3 |
| Murmansk | 68 | 58 | 33 | 03 | 46 | 6 | 6.1 |
| Mutoray | 61 | 20 | 100 | 30 | - | - | 2.0 |
| Mys Chelyuskin | 77 | 43 | 104 | 17 | 13 | 7 | 6.9 |
| Mys Kamennyy | 68 | 28 | 73 | 36 | 14 | 7 | 6.9 |
| Mys Kronotskiy | 54 | 45 | 162 | 08 | - | 5 | 4.4 |
| Mys Leskina | 72 | 17 | 79 | 42 | 11 | 7 | 7.2 |
| Mys Navarin | 62 | 16 | 179 | 08 | 10 | 7 | 9.7 |
| Mys Osten-Saken | 76 | 14 | 98 | 50 | - | 7 | 6.2 |
| Mys Ozernoy | 57 | 43 | 163 | 19 | - | 6 | 5.3 |
| Mys Shmidta | 68 | 55 | 179 | 29(W) | 7 | 7 | 5.7 |
| Mys Sosunova | 46 | 31 | 138 | 16 | - | 5 | 6.9 |
| Mys Sterlegova | 75 | 25 | 88 | 54 | 7 | 7 | 7.3 |
| Mys Syurkum | 50 | 06 | 140 | 41 | - | 5 | 6.2 |

| Station | Coordinates Lat(N) | | Long(E) | | Elevation (m) | No. months Temp. < 0°C | Ave. 5-mo. (Nov-Mar) wind speed (m/s) |
|---|---|---|---|---|---|---|---|
| Mys Tigrovyy | 43° | 56' | 58° | 44' | - | 2 | 4.6 |
| Mys Uelen | 66 | 10 | 169 | 50(W) | 7 | 7 | 6.6 |
| Mys Yelizavety | 54 | 25 | 142 | 43 | 77 | 6 | 6.3 |
| Nakanno | 62 | 52 | 108 | 26 | - | 7 | 1.3 |
| Nakhichevan | 39 | 12 | 45 | 25 | 875 | 3 | 1.4 |
| Nal'chik | 43 | 30 | 43 | 37 | 441 | 2 | 1.9 |
| Napas | 59 | 56 | 81 | 59 | 89 | 7 | 2.7 |
| Nar'yan Mar | 67 | 39 | 53 | 01 | 7 | 7 | 5.3 |
| Narva | 59 | 23 | 28 | 12 | - | 5 | 4.6 |
| Naryn | 41 | 26 | 76 | 00 | 2048 | 6 | 1.5 |
| Nayakhan | 61 | 55 | 159 | 00 | 22 | 7 | 7.9 |
| Nazimovo | 59 | 30 | 90 | 58 | - | - | 3.0 |
| Nelyaty | 56 | 30 | 115 | 40 | 474 | 7 | 1.5 |
| Nerchinskiy Zavod | 51 | 19 | 119 | 37 | 626 | - | 0.9 |
| Nevel'sk | 46 | 40 | 141 | 52 | 6 | 4 | 6.0 |
| Nevinnomyssk | 44 | 38 | 41 | 38 | 333 | 3 | 4.5 |
| Nevon | 58 | 02 | 102 | 44 | 231 | 7 | 1.6 |
| Nikol'skoye | 55 | 12 | 165 | 59 | 6 | 5 | 9.3 |
| Nikolayev | 46 | 58 | 32 | 00 | 19 | 3 | 3.8 |
| Nikolayevsk na Amure | 53 | 09 | 140 | 42 | 42 | 6 | 3.4 |
| Nizhneangarsk | 55 | 47 | 109 | 33 | - | 7 | 2.1 |
| Nizhneilimsk | 57 | 11 | 103 | 16 | - | 7 | 1.7 |
| Nizhnekolymsk | 68 | 32 | 160 | 56 | 8 | 7 | 2.4 |
| Nizhneudinsk | 54 | 53 | 99 | 02 | 410 | 5 | 1.8 |
| Noginskiy | 64 | 32 | 91 | 10 | - | - | 2.3 |
| Nogliki | 51 | 50 | 143 | 08 | 10 | 6 | 4.9 |
| Norsk | 52 | 21 | 129 | 55 | 207 | 5 | 1.2 |
| Noril'sk | 69 | 20 | 88 | 06 | - | 6 | 6.1 |
| Novgorod | 58 | 31 | 31 | 17 | - | - | 5.4 |
| Novosibirsk | 55 | 02 | 82 | 54 | 162 | 5 | 4.8 |
| Novo-Yerudinskiy | 59 | 45 | 93 | 32 | - | - | 1.8 |
| Novyy Port | 67 | 40 | 72 | 52 | 5 | 7 | 7.3 |
| Odessa | 46 | 29 | 30 | 38 | 64 | 2 | 5.4 |
| Odinnadtsaty | 55 | 54 | 119 | 36 | 1079 | 7 | 1.9 |
| Okhotsk | 59 | 22 | 143 | 12 | 6 | 7 | 5.1 |
| Okhotskiy Perevoz | 61 | 53 | 135 | 33 | - | 7 | 0.7 |
| Oktyabr'skoye | 62 | 27 | 66 | 03 | 38 | 7 | 2.8 |
| Ol'khon | 53 | 03 | 106 | 54 | 468 | 6 | 3.3 |
| Oleminsk | 60 | 24 | 120 | 55 | 125 | 7 | 2.2 |
| Olenek | 68 | 30 | 112 | 26 | 127 | 7 | 1.3 |
| Olonets | 60 | 59 | 32 | 58 | 15 | 5 | 4.4 |
| Opochka | 56 | 42 | 28 | 43 | - | - | 3.7 |
| Oymyakon | 63 | 28 | 142 | 49 | - | 6 | 0.4 |
| Onguday | 50 | 45 | 86 | 09 | - | 5 | 0.3 |
| Onor | 50 | 14 | 142 | 35 | 180 | 6 | 2.4 |
| Ordzhonikidze | 43 | 03 | 44 | 39 | 670 | 2 | 1.2 |

| Station | Coordinates Lat(N) | | Long(E) | | Elevation (m) | No. months Temp. < 0°C | Ave. 5-mo. (Nov-Mar) wind speed (m/s) |
|---|---|---|---|---|---|---|---|
| Orel | 52° | 55' | 36° | 05' | - | 5 | 6.0 |
| Orenburg | 51 | 45 | 55 | 06 | 109 | 5 | 4.3 |
| Orlik | 52 | 30 | 99 | 49 | 1407 | 7 | 1.5 |
| Ostrov Andreya | 76 | 53 | 111 | 25 | - | - | 5.6 |
| Ostrov Domashniy | 79 | 30 | 91 | 08 | 3 | 7 | 5.8 |
| Ostrova Izvestiy Tsik | 75 | 55 | 82 | 30 | - | - | 6.2 |
| Ostrova Krasoflotskiye | 79 | 40 | 98 | 45 | - | - | 5.5 |
| Ostrov Malyy Taymyr | 78 | 08 | 107 | 12 | - | - | 5.6 |
| Ostrov Morzhovets | 66 | 44 | 42 | 30 | - | 6 | 7.7 |
| Ostrov Prebrazheniya | 74 | 40 | 112 | 56 | 6 | 7 | 5.1 |
| Ostrov Russkiy | 77 | 10 | 96 | 25 | 10 | 7 | 6.4 |
| Ostrov Uyedineniya | 77 | 30 | 82 | 12 | 10 | 7 | 6.6 |
| Ostrov Vize | 79 | 30 | 76 | 59 | 18 | 7 | 6.5 |
| Oymyakon | 63 | 28 | 142 | 49 | - | 7 | 0.4 |
| Ozernovskiy | 51 | 29 | 156 | 29 | 6 | 6 | 8.9 |
| Ozero Taymyr | 74 | 30 | 102 | 30 | - | 7 | 5.5 |
| Padany | 63 | 17 | 33 | 25 | - | 6 | 3.9 |
| Palana | 59 | 06 | 159 | 59 | - | 7 | 3.9 |
| Panfilov | 44 | 10 | 80 | 04 | 640 | 3 | 1.9 |
| Parnu | 58 | 24 | 24 | 32 | - | 4 | 5.3 |
| Pavlodar | 52 | 17 | 76 | 57 | 146 | 5 | 5.3 |
| Penza | 53 | 08 | 45 | 01 | 174 | 5 | 5.4 |
| Perm | 58 | 01 | 56 | 18 | 160 | 5 | 5.0 |
| Petropavlovsk | 54 | 50 | 69 | 09 | 135 | 5 | 5.2 |
| Petropavlovsk Kamchatskiy | 52 | 58 | 158 | 45 | 7 | 5 | 6.6 |
| Petrozavodsk | 61 | 49 | 34 | 20 | - | 5 | 4.8 |
| Pikhtovka | 56 | 00 | 82 | 42 | - | 6 | 3.3 |
| Pil'vo | 50 | 03 | 142 | 10 | 54 | 5 | 5.2 |
| Pinsk | 52 | 07 | 26 | 08 | 143 | 4 | 4.7 |
| Pkhusun | 43 | 22 | 134 | 48 | 7 | 5 | 4.0 |
| Podkamennaya Tunguska | 61 | 36 | 90 | 09 | 60 | 7 | 3.1 |
| Pogranichnyy | 44 | 24 | 131 | 23 | - | 5 | 3.8 |
| Poligus | 62 | 00 | 94 | 41 | - | - | 0.6 |
| Poliny Osipenko | 52 | 25 | 136 | 28 | - | - | 1.4 |
| Poronaysk | 49 | 13 | 143 | 06 | 4 | 5 | 3.2 |
| Potapovo | 68 | 40 | 86 | 20 | - | - | 4.6 |
| Preobrazhenka | 60 | 02 | 108 | 05 | - | 7 | 2.3 |
| Prikumsk | 44 | 48 | 44 | 10 | 118 | 2 | 3.7 |
| Priozersk | 61 | 02 | 30 | 07 | - | - | 3.1 |
| Proliv Yugorskiy Shar | 69 | 49 | 60 | 45 | 13 | 7 | 8.9 |
| Provideniya | 64 | 26 | 173 | 14(W) | 3 | 7 | 4.9 |
| Pskov | 57 | 50 | 28 | 21 | 42 | 5 | 4.0 |
| Pudozh | 61 | 48 | 36 | 32 | - | 5 | 3.6 |
| Pytalovo | 57 | 04 | 27 | 54 | - | - | 4.3 |
| Rang-kul' | 38 | 28 | 74 | 22 | - | 5 | 2.6 |
| Reboly | 63 | 49 | 30 | 47 | - | 6 | 3.5 |

| Station | Coordinates Lat(N) | | Long(E) | | Elevation (m) | No. months Temp. < 0°C | Ave. 5-mo. (Nov-Mar) wind speed (m/s) |
|---|---|---|---|---|---|---|---|
| Riga | 56° | 58' | 24° | 04' | 3 | 4 | 5.4 |
| Romny | 44 | 45 | 134 | 28 | 216 | 5 | 1.7 |
| Rostov na Donu | 47 | 15 | 39 | 49 | 77 | 3 | 5.4 |
| Rubtsovsk | 51 | 30 | 81 | 13 | 214 | 5 | 5.8 |
| Ryazan' | 54 | 37 | 39 | 43 | 135 | 5 | 5.5 |
| Salekhard | 66 | 32 | 66 | 32 | 35 | 7 | 4.1 |
| Sam-Pervyy | 45 | 29 | 56 | 06 | 82 | 3 | 4.8 |
| Saratov | 51 | 34 | 46 | 02 | 156 | 5 | 5.3 |
| Sarny | 51 | 12 | 26 | 37 | 153 | 3 | 3.4 |
| Saskylakh | 71 | 58 | 114 | 05 | 24 | 7 | 3.4 |
| Semipalatinsk | 50 | 21 | 80 | 15 | 206 | 5 | 3.1 |
| Serov | 59 | 30 | 60 | 32 | 132 | 5 | 2.9 |
| Severnoye | 56 | 21 | 78 | 21 | 123 | 5 | 2.7 |
| Severo-Yeniseyskiy | 60 | 22 | 93 | 01 | - | - | 3.5 |
| Seymchan | 62 | 55 | 152 | 25 | 207 | 7 | 1.0 |
| Shenkursk | 62 | 06 | 42 | 54 | 50 | 5 | 4.1 |
| Shepetkovo | 66 | 33 | 159 | 25 | 125 | 7 | 1.2 |
| Shepetovka | 50 | 10 | 27 | 03 | 260 | 4 | 4.6 |
| Shimanovsk | 51 | 59 | 127 | 39 | 276 | 5 | 2.3 |
| Shologontsy | 66 | 15 | 114 | 17 | 235 | 7 | 0.8 |
| Simferopol' | 45 | 01 | 33 | 59 | 205 | 1 | 4.8 |
| Skovorodino | 54 | 00 | 123 | 58 | 399 | 7 | 2.0 |
| Skuratovo | 53 | 34 | 37 | 03 | 248 | 5 | 5.9 |
| Slautnoye | 63 | 11 | 167 | 52 | 304 | 7 | 4.6 |
| Slavgorod | 52 | 58 | 78 | 39 | 125 | 5 | 5.3 |
| Smolensk | 54 | 45 | 32 | 04 | 241 | 5 | 4.8 |
| Soroki | 48 | 09 | 28 | 18 | - | - | 4.9 |
| Sortavala | 61 | 42 | 30 | 41 | - | 5 | 3.9 |
| Srednekolymsk | 67 | 27 | 153 | 41 | 27 | 7 | 1.7 |
| Stanovishche (Camp na Ser) | 70 | 35 | 72 | 37 | 15 | 7 | 6.5 |
| Stanovishche Tiuteyykha | 71 | 23 | 67 | 33 | 45 | 7 | 7.6 |
| Staraya Russa | 58 | 00 | 31 | 23 | - | - | 4.5 |
| Stravropol' | 45 | 03 | 41 | 59 | 574 | 3 | 4.7 |
| Strelka Chunya | 61 | 45 | 102 | 48 | - | - | 2.0 |
| Sukhanovka | 51 | 21 | 139 | 06 | 20 | 5 | 4.1 |
| Sukhaya Tunguska | 65 | 10 | 87 | 55 | - | - | 3.5 |
| Sukhobuzimskoye | 56 | 30 | 93 | 16 | - | 5 | 3.4 |
| Suntar | 62 | 09 | 117 | 39 | 124 | 7 | 1.9 |
| Sura | 63 | 35 | 45 | 38 | 50 | 6 | 3.5 |
| Surgut | 61 | 15 | 73 | 30 | 43 | 6 | 4.7 |
| Sutungu | 46 | 45 | 136 | 01 | - | 5 | 2.6 |
| Sverdlovsk | 58 | 48 | 60 | 38 | 237 | 5 | 3.9 |
| Svetlyy | 56 | 26 | 115 | 55 | - | 7 | 1.6 |
| Syktyvkar | 61 | 40 | 50 | 51 | 96 | - | 4.3 |
| Sym | 60 | 20 | 88 | 23 | - | - | 2.3 |
| Tallinn | 59 | 25 | 24 | 48 | 43 | 4 | 5.6 |

| Station | Coordinates Lat(N) | | Long(E) | | Elevation (m) | No. months Temp. < 0°C | Ave. 5-mo. (Nov-Mar) wind speed (m/s) |
|---|---|---|---|---|---|---|---|
| Tambey | 71° | 30' | 71° | 50' | 8 | 7 | 7.1 |
| Tambov | 52 | 43 | 41 | 27 | - | 5 | 4.3 |
| Tanguy | 55 | 23 | 100 | 58 | - | 7 | 1.5 |
| Tara | 56 | 54 | 74 | 23 | 74 | 5 | 4.0 |
| Tarasity-yar | 73 | 02 | 88 | 10 | - | 7 | 5.4 |
| Tarko Sale | 64 | 55 | 77 | 49 | 27 | 7 | 3.2 |
| Tartu | 58 | 23 | 26 | 43 | - | 5 | 4.0 |
| Tashtyp | 52 | 48 | 85 | 54 | 455 | 5 | 2.9 |
| Taimba | 60 | 18 | 98 | 58 | 168 | 7 | 1.1 |
| Tayshet | 55 | 57 | 98 | 00 | - | 5 | 3.4 |
| Tazovskiy | 67 | 28 | 78 | 44 | 4 | 7 | 6.4 |
| Teli | 51 | 02 | 90 | 14 | - | - | 0.5 |
| Tembenchi | 64 | 57 | 98 | 51 | - | - | 0.8 |
| Temir | 49 | 09 | 57 | 07 | 235 | 5 | 5.2 |
| Terney | 45 | 02 | 136 | 40 | 11 | 5 | 6.6 |
| Tikhvin | 59 | 39 | 33 | 31 | - | - | 4.2 |
| Tiksi | 71 | 35 | 128 | 55 | 7 | 7 | 5.8 |
| Tisul' | 55 | 45 | 88 | 19 | 189 | 5 | 4.7 |
| Tobol'sk | 58 | 09 | 68 | 11 | 43 | 5 | 4.1 |
| Tokma | 58 | 16 | 105 | 54 | - | 7 | 1.5 |
| Tokubay Mogila | 45 | 57 | 77 | 14 | - | 5 | 2.1 |
| Tomsk | 56 | 26 | 84 | 58 | 121 | 5 | 5.5 |
| Toora-Khem | 52 | 28 | 96 | 09 | - | - | 0.6 |
| Trofimovsk | 72 | 36 | 127 | 02 | - | 7 | 8.1 |
| Troitsk | 57 | 18 | 94 | 58 | 163 | 6 | 1.8 |
| Troitsko-Pechorskoye | 62 | 42 | 56 | 12 | 107 | 7 | 3.3 |
| Troitskoye | 49 | 27 | 136 | 34 | 29 | 5 | 4.0 |
| Tselinograd | 51 | 08 | 71 | 22 | 348 | 5 | 6.2 |
| Tsyp-Navolok | 69 | 43 | 33 | 05 | 8 | 6 | 9.8 |
| Tula | 54 | 12 | 37 | 27 | 165 | 5 | 5.3 |
| Tulun | 54 | 35 | 100 | 33 | - | 7 | 0.9 |
| Tungokochen | 53 | 34 | 115 | 34 | 812 | 7 | 1.1 |
| Tuoy Khaya | 62 | 32 | 111 | 14 | 239 | 7 | 2.3 |
| Tura | 64 | 17 | 100 | 15 | 139 | 7 | 1.6 |
| Turan | 52 | 08 | 93 | 55 | - | - | 1.2 |
| Turkestan | 43 | 16 | 68 | 13 | 209 | 2 | 2.6 |
| Turochak | 52 | 16 | 87 | 10 | - | 5 | 0.8 |
| Turukhansk | 65 | 49 | 87 | 59 | 32 | 7 | 3.9 |
| Tymlat | 59 | 31 | 163 | 07 | 304 | 7 | 4.4 |
| Tyrma | 50 | 04 | 132 | 08 | 313 | 5 | 1.0 |
| Tyumen' | 57 | 09 | 65 | 30 | 103 | 5 | 4.7 |
| Ucharal | 46 | 10 | 80 | 56 | 388 | 4 | 3.3 |
| Ufa | 54 | 45 | 56 | 00 | 196 | 5 | 4.6 |
| Uglegorsk | 49 | 05 | 142 | 04 | 53 | 5 | 5.5 |
| Uman' | 48 | 46 | 30 | 14 | 216 | 4 | 4.8 |
| Umba | 66 | 41 | 34 | 18 | - | - | 5.0 |

| Station | Coordinates Lat(N) | | Long(E) | | Elevation (m) | No. months Temp. < 0°C | Ave. 5-mo. (Nov-Mar) wind speed (m/s) |
|---|---|---|---|---|---|---|---|
| Ust Maya | 60° | 23' | 134° | 27' | 175 | 7 | 1.1 |
| Ust' Bol'sheretsk | 52 | 40 | 156 | 14 | 7 | 6 | 6.6 |
| Ust' Kamchatsk | 56 | 13 | 162 | 28 | 6 | 6 | 5.8 |
| Ust' Kamo | 60 | 43 | 97 | 29 | - | 7 | 1.2 |
| Ust' Kut | 56 | 46 | 105 | 40 | - | 7 | 1.1 |
| Ust' Port | 69 | 39 | 84 | 24 | 27 | 7 | 5.9 |
| Ust' Shchugor | 64 | 16 | 57 | 37 | 75 | - | 3.4 |
| Ust' Tsil'ma | 65 | 27 | 52 | 10 | 27 | 7 | 4.7 |
| Ust' Voyampolka | 58 | 30 | 159 | 10 | 7 | 6 | 6.2 |
| Ust' Yudoma | 59 | 11 | 135 | 09 | 211 | 7 | 1.0 |
| Uyaly | 44 | 35 | 61 | 09 | 55 | 3 | 4.3 |
| Uzhgorod | 48 | 38 | 22 | 16 | 118 | 3 | 2.5 |
| Uzhur | 55 | 18 | 89 | 50 | - | - | 3.8 |
| Vanavara | 60 | 22 | 102 | 16 | 260 | 7 | 1.6 |
| Vanzhil'kynak | 60 | 22 | 84 | 06 | - | 7 | 2.1 |
| Velikaya Kema | 45 | 28 | 137 | 15 | - | 4 | 5.6 |
| Velikiye | 56 | 21 | 30 | 31 | 103 | 5 | 3.1 |
| Vel'mo Pervoye | 61 | 11 | 93 | 05 | - | - | 1.4 |
| Vengerovo | 55 | 41 | 76 | 45 | - | 5 | 4.0 |
| Ventspils | 57 | 22 | 21 | 33 | 4 | 2 | 6.6 |
| Vereshchagino | 64 | 14 | 87 | 37 | - | - | 3.3 |
| Verkhne Imbatskoye | 63 | 11 | 87 | 58 | 39 | 7 | 3.6 |
| Verkhnyaya Mishikha | 51 | 38 | 105 | 35 | 1280 | 7 | 3.0 |
| Verkhoyansk | 67 | 33 | 133 | 23 | - | 7 | 0.6 |
| Verkhniy-Baskunchak | 48 | 13 | 46 | 44 | 35 | 4 | 4.3 |
| Vikulovo | 56 | 49 | 70 | 37 | 70 | 5 | 3.3 |
| Vilyuysk | 63 | 46 | 121 | 37 | 107 | 7 | 1.9 |
| Vitim | 59 | 28 | 112 | 34 | 193 | 7 | 2.4 |
| Vivi | 63 | 54 | 97 | 50 | - | - | 1.6 |
| Vladivostok | 43 | 70 | 131 | 54 | 138 | 5 | 7.1 |
| Volkhov | 59 | 49 | 32 | 22 | - | - | 3.9 |
| Volgograd | 48 | 41 | 44 | 21 | 145 | 4 | 6.6 |
| Volnovakha | 47 | 36 | 37 | 30 | - | - | 5.2 |
| Volochanka | 71 | 00 | 94 | 28 | - | 7 | 3.5 |
| Vologda | 59 | 17 | 39 | 52 | 118 | 5 | 6.1 |
| Vorenzha | 63 | 53 | 35 | 15 | - | 6 | 3.3 |
| Vorkuta | 67 | 29 | 64 | 01 | 180 | 7 | 6.3 |
| Vorogovo | 61 | 02 | 89 | 35 | 64 | 7 | 3.8 |
| Voronezh | 51 | 47 | 39 | 10 | 164 | 5 | 5.2 |
| Vostochnyy | 48 | 17 | 142 | 38 | 6 | 5 | 4.2 |
| Vozhega | 60 | 28 | 40 | 12 | 178 | 5 | 4.1 |
| Vyborg | 60 | 42 | 28 | 45 | - | - | 3.8 |
| Vyshniy | 57 | 35 | 34 | 34 | 160 | 5 | 3.2 |
| Yakutsk | 62 | 05 | 129 | 45 | 103 | 7 | 2.0 |
| Yaral'in | 67 | 00 | 110 | 00 | 230 | 7 | 1.8 |
| Yartsevo | 60 | 14 | 90 | 12 | 57 | 7 | 3.8 |

| Station | Coordinates Lat(N) | | Long(E) | | Elevation (m) | No. months Temp. < 0°C | Ave. 5-mo. (Nov-Mar) wind speed (m/s) |
|---|---|---|---|---|---|---|---|
| Yashkul' | 46° | 11' | 45° | 21' | - | 4 | 5.6 |
| Yekaterino Nikol'sk | 47 | 44 | 130 | 58 | 74 | 5 | 3.5 |
| Yelabuga | 55 | 46 | 52 | 04 | 89 | 5 | 3.5 |
| Yelets | 52 | 38 | 38 | 31 | 130 | 5 | 5.5 |
| Yelizovo | 53 | 10 | 158 | 24 | - | 6 | 3.0 |
| Yemtsa | 63 | 04 | 40 | 21 | 107 | 5 | 3.1 |
| Yeniseysk | 58 | 27 | 92 | 10 | 78 | 7 | 2.4 |
| Yerbogachen | 61 | 16 | 108 | 01 | 278 | 7 | 1.6 |
| Yerevan | 40 | 08 | 44 | 28 | 907 | 1 | 0.6 |
| Yermakovskoye | 53 | 16 | 92 | 24 | 301 | - | 2.0 |
| Yerofey Pavlovich | 53 | 58 | 121 | 56 | - | 7 | 1.2 |
| Yesil' | 51 | 53 | 66 | 20 | 221 | 5 | 4.2 |
| Yessey | 68 | 29 | 102 | 10 | 199 | 7 | 2.2 |
| Yur'yevets | 57 | 20 | 43 | 07 | 132 | 5 | 4.5 |
| Yushkozero | 64 | 45 | 32 | 07 | - | 6 | 3.0 |
| Yuzhno-Sakhalinsk | 46 | 55 | 142 | 44 | - | 5 | 4.5 |
| Zaporozh'ye | 47 | 48 | 35 | 12 | 86 | 3 | 5.6 |
| Zavitinsk | 50 | 07 | 129 | 28 | 242 | 5 | 2.8 |
| Zaysan | 47 | 28 | 84 | 55 | 602 | 5 | 1.8 |
| Zemetchino | 53 | 30 | 42 | 37 | 129 | 5 | 4.5 |
| Zeya | 53 | 54 | 127 | 14 | 232 | 6 | 2.1 |
| Zherdevka | 51 | 51 | 41 | 48 | - | 5 | 4.1 |
| Zhigalovo | 54 | 48 | 105 | 08 | - | 7 | 1.4 |
| Zhigansk | 66 | 46 | 123 | 24 | 57 | 7 | 3.2 |
| Zhitkovichi | 52 | 14 | 27 | 52 | - | 4 | 4.3 |
| Zima | 53 | 55 | 102 | 40 | - | 6 | 2.0 |
| Zimnegorskyy | 65 | 28 | 39 | 44 | 81 | 6 | 6.3 |
| Zlatoust | 55 | 10 | 59 | 41 | 457 | 5 | 4.6 |
| Zmeinogorsk | 51 | 10 | 82 | 13 | 387 | 5 | 3.9 |
| Znamenka | 51 | 30 | 95 | 36 | - | - | 0.8 |
| Zyryanka | 65 | 44 | 150 | 54 | 39 | 7 | 2.0 |

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